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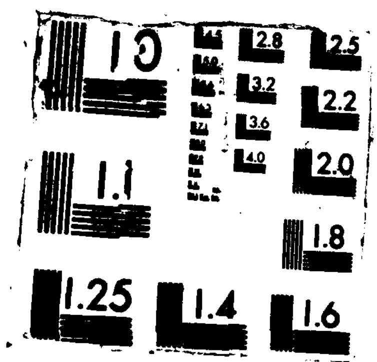
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Submitted for publication as a Journal Article – not a technical report –

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BEHAVIORAL AND ORGANIZATIONAL CONSIDERATIONS IN THE DESIGN OF INFORMATION SYSTEMS AND PROCESSES FOR PLANNING AND DECISION SUPPORT

by

CONTRACT NO: N00014-80-C-0542

Andrew P. Sage

WORK UNIT NO. NR 197-065

June 1981

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

DEPARTMENT OF ENGINEERING SCIENCE AND SYSTEMS

UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VIRGINIA 22901

Behavioral and Organizational Considerations in the Design of Information Systems and Processes for Planning and Decision Support

by

Andrew P. Sage
Department of Engineering Science and Systems
University of Virginia
Charlottesville, Virginia 22901

Abstract

This paper discusses determinants of performance of systems and processes for planning and decision support. It is directed at people who design such systems and processes, who use such systems and processes, and who manage organizations in which these may be used. The literature cited is associated with several areas including psychology, organizational behavior and design, information science, management science, computer science, and related disciplines. We are especially interested in performance determinants and design requirements for systems and processes for planning and decision support. A number of areas where additional research appears needed are mentioned, and some recommendations and interpretations are given concerning both contemporary efforts and needed future efforts.

This work was partially supported by the Office of Naval Research under Contract No. N0014-80-C-0542. Helpful comments were provided by Dr. Chelsea C. White, III, Adolfo Lagomasino, Elbert White, and Ranju Rao.

1. Introduction

That there is much interest in planning and decisionmaking efforts to determine effective public and private sector policies is evident by the number of recent texts and case studies devoted to these topics [2, 4, 13, 18, 20, 21, 44, 45, 48, 51, 80, 84-86, 89, 104, 105, 108, 134, 135, 139, 141, 150, 178, 179, 198, 212, 219-222, 236, 243, 283, 293, 318-320, 334, 359, 361, 363, 377, 394, 397, 399, 400, 412]. These works concern, in part, the numerous complexities associated with practical implementation of the results of systemic efforts for planning and decision support. Advances in digital computer technology; coupled with advances in systems science, systems methodology and design, and systems management; suggest extension of the information analysis and display capability provided by management information systems to include interpretation and aggregation of information and values such as to result in decision support systems (DDS) or planning and decision support systems. There is a growing literature in this area [5, 36, 39-41, 55, 76, 110, 133, 138, 224, 226, 227, 239, 240, 258, 309, 350, 356, 366] and this indicates much contemporary interest and activity.

There are a number of requirements for design success with respect to systems for planning and decision support. These involve a considerable number of disciplines. The result of not making appropriate use of pertinent contributions from a number of disciplines in the design of systems for planning and decision support is likely to be a

system or process that is deficient in one or more important ways. The purpose of this effort is to discuss, from a systems engineering perspective, some of the many requirements for design success in this area.

It is possible to disaggregate planning and decisionmaking processes into a number of steps. In essence, they are purposeful futuristic efforts which involve the entire systems engineering process [301-305, 307, 308] and can, therefore, be described by any of a number of frameworks for systems engineering such as the three or the seven step framework which involves:

1. formulation of the issue
   - a) problem definition (determination of needs, constraints, alterables)
   - b) value system design (determination of objectives and objectives measures)
   - c) system synthesis (identification of possible decisions or action alternatives and measures of the accomplishment of these)
2. analysis of the issue
   - d) systems analysis and modeling (determination of the structure of the decision situation, the impacts of identified decisions or action alternatives and the sensitivity of these to possible change in conditions)
   - e) optimization or refinement of alternatives (adjustment of parameters or activities such that each identified decision is the best possible in accordance with the value system)

3. interpretation of the issue

   f) evaluation and decisionmaking (each possible decision alternative is evaluated, prioritized, and one or more alternatives are selected for implementation action)

   g) planning for action (commitment of resources are made and implementation is accomplished)

Janis and Mann [177] have identified a four stage model of the decisionmaking process. Figure 1.1 presents a slightly modified version of this decision process model. We note that it contains the same essential steps involved in the systems engineering process. Of particular interest are the questions asked at each step of the process. We will elaborate upon this model, and other models, of the decisionmaking process in our efforts to follow.

Comprehensive efforts involving decisionmaking will be complex because of the many disciplines and areas involved as well as because

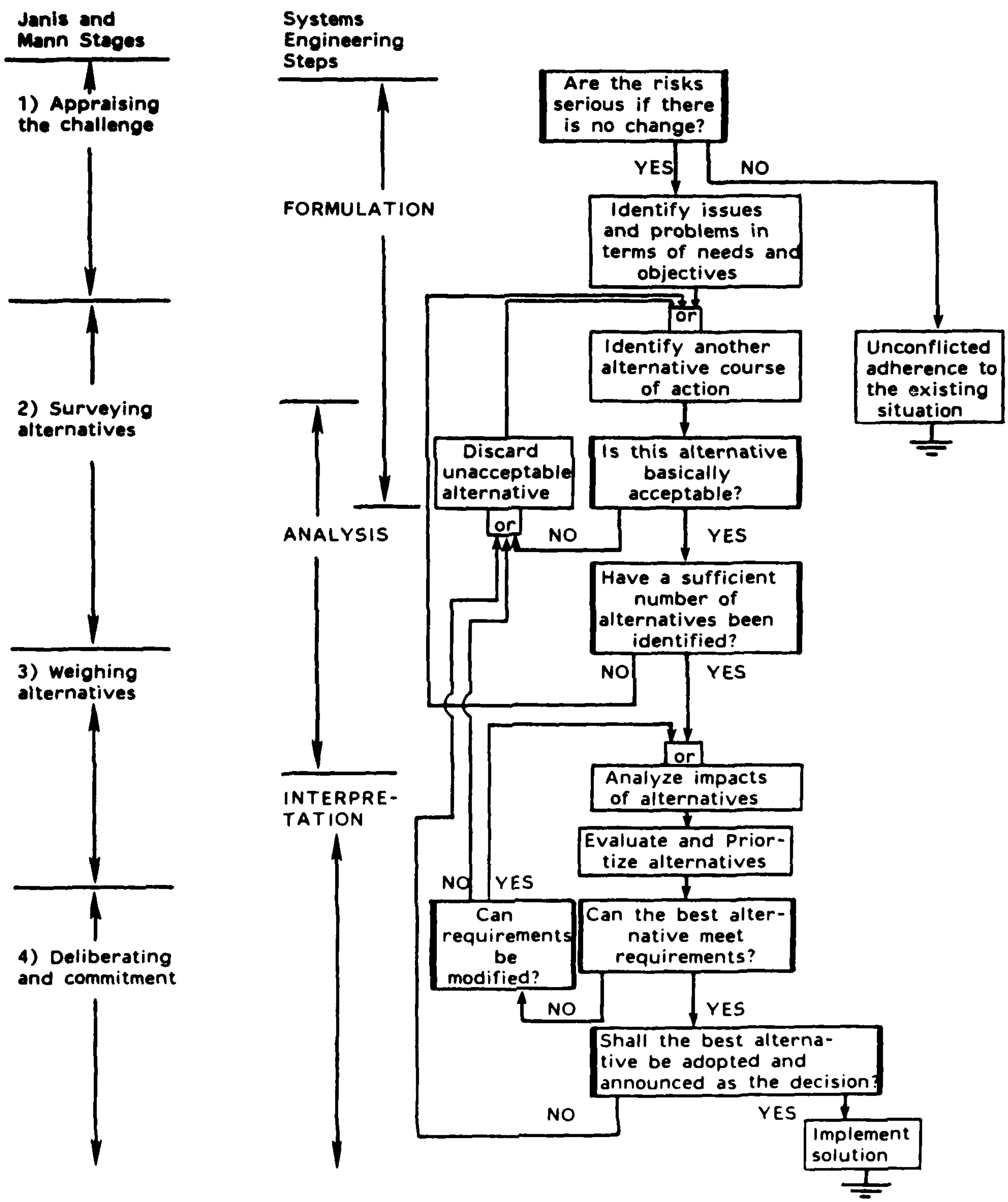


Figure 1.1 Systems Engineering Interpretation of The Decision Process Model of Janis and Mann

of the subject matter itself. Probably, the formal study of decisionmaking first began with the rational economic man concepts of the 18th century mathematicians Cramer and Bernoulli who explained the St. Petersburg paradox. Since then there have been many workers from a large number of disciplines who have been concerned with various types of decisionmaking studies, and the provision of assistance to enhance the understanding of rationale for plans and decisions as well as improvements in the efficiency, effectiveness, and equity of the resource allocations that constitute planning and decisionmaking.

Contemporary choicemaking issues in the public and private sector are complex, contain much uncertainty, and require inputs from many sectors for full understanding and resolution. Many writers have indicated bounded rationality limits in decisionmaking that would appear to make provision of information system adjuvants for choicemaking normatively very desirable. Such planning and decision support systems could, in principle, provide decisionmakers with rapid access to the information and knowledge needed to enhance decision quality. Unfortunately this promise of enhanced decision quality has not always been realized in practice. There are, doubtlessly, a number of causitive factors inhibiting the potential benefits possible from information systems for planning and decision support. Principal among these factors which, at present, pose fundamental limits to information system success appear to be:

(1) the need to insure substantive or input output rationality, such that evaluations of plans and decisions are veridical;

(2) the need to insure process rationality, such that the information system accommodates the capabilities of, and the constraints placed upon, the user;

(3) the need to understand and cope with human cognitive limitations as they affect the formulation, analysis, and interpretation of decision situations and alternatives; and

(4) the need to understand and integrate the normative or prescriptive components with the descriptive components of decision situations in order to evolve realistic adjuvants for the formulation, analysis, and interpretation of decision options.

This paper presents a survey, status report, integration and interpretation of research from a diversity of areas that supports the design of information systems capable of coping with the needs and fundamental limits to improved judgment just mentioned. We discuss and describe:

(1) the cognitive styles of decisionmakers,

(2) individual human information processing in decision situations and biases in the acquisition, analysis, and interpretation of information,

(3) decision rules for individual decision situations,

(4) contingency task structural models of decision situations, and

(5) decision making frameworks, organizational settings, and information processing in group and organizational decision situations.

The literature in this area is enormous. But there is the need for efforts to integrate it from the perspective of systems engineering design of information systems for planning and decision support. There are a number of recent surveys available that discuss one, or a limited number, of the topics important for the design of planning and decision support systems. These include the surveys of Barron [27]; Benbasat and Taylor [35]; Bettman [37]; Craik [67]; Dunnette [87]; Einhorn, Kleinmuntz, and Kleinmuntz [95]; Einhorn and Hogarth [98]; Ericsson and Simon [99]; Hammond, McClelland, and Mumpower [142]; Hammond [143]; Hogarth [159]; Hogarth and Makridakis [161]; Johnson and Huber [179]; Kassin [190]; Keen [193]; Libby and Fishburn [214]; Libby and Lewis [215]; Mintzberg [248]; Nisbett and Ross [264]; Nutt [266]; Robey and Taggart [292]; Sage and White [304]; Schneider and Shiffrin [313]; Slovic and Lichtenstein [345]; Slovic, Fishhoff, and Lichtenstein [348]; Svenson [365]; and Zmud [415]. This work attempts a selective integration of this voluminous literature and extensions and interpretations of it from the perspective of ultimate potential usefulness for the design of information systems for planning and decision support. Generally, references are provided only to published literature of the last half decade with limited references to earlier seminal literature and reports. This was felt desirable in order to limit the reference list to an almost manageable size. Despite our attempt to make this report comprehensive, it

doubtlessly fails to incorporate the important contributions of a number of authors. And there are doubtlessly unintentional misattributions and misinterpretations as well. For this apologies are offered and forgiveness requested.

2. Cognitive Styles

It is becoming increasingly clear that it is necessary to incorporate not only problem characteristics, but also problem solver or decisionmaker characteristics, into the design of information systems for planning and decision support. A deficiency in some past designs has been the neglect of the human decisionmakers' role and characteristics, and their effects. Essentially all available evidence suggests that problem characteristics and user characteristics influence the planning and choice strategies adopted by the decisionmaker. This section discusses a number of cognitive style models from these perspectives.

Mason and Mitroff [238] have suggested that each person possesses a particular specific psychological cognitive style or "personality" and that each personality type utilizes information in different ways. In their research on MIS design, they claim that an information system consists of a person of a certain psychological type who faces a problem in some organizational context for which needed evidence to arrive at a solution is made available through some mode of presentation.

There are five essential variables in the information system characterization of Mason and Mitroff. Each of these are disaggregated into subelements. Mason and Mitroff characterize the psychological-type variable according to the Jungian stereotypology. In this typology, people differ according to their preference for information acquisition and analysis, and the preferred approach to information evaluation and interpretation. At extremes

in the information acquisition dimension are sensing oriented or sensation types, who prefer detailed well structured problems and who like precise routine tasks, and intuitive-oriented type people, who dislike precise routine structured tasks and perceive issues wholistically. At extremes in the information evaluation dimension are feeling-oriented people, who rely on emotions, situational ethics, and personal values in making decisions; and thinking oriented individuals, who rely on impersonal logical arguments in reaching decisions.

Mason and Mitroff characterize the problem variable into structured and unstructured problems. These may be further divided into decisions under certainty, decisions under risk, and decisions under uncertainty. The organizational context variable is characterized as strategic planning, management control, and operational control. The method-of-evidence-generation variable involves five types of inquiry systems: the data based Lockean inquiry system, the model based Leibnitzian inquiry system, the multiple model based Kantian inquiry system, the conflicting model based Hegelian inquiry system, and the learning system based Singerian-Churchmanian inquiry system. (254). A fifth variable, mode of presentation, includes personalistic modes of presentation such as one-on-one contact as in drama and art; and impersonalistic modes, such as abstract analytical models and company reports. These latter four variables do not formally relate to cognitive styles, and some further comment on them is contained in other portions of our effort. A number of works by Mason and Mitroff and their colleagues discuss

various aspects of this categorization [252-254]. Of interest in this regard is a work by Kilman [200] which suggests the design of organizations with the Jungian personality characteristics of individuals.

Among the many other studies which have emphasized the need to incorporate decisionmaker characteristics into information system design is that of Doktor and Hamilton [78]. They studied the influence of cognitive style on the acceptance of management science recommendations, and found a strong correlation between the decisionmaker's cognitive style and willingness to accept these recommendations. They found that differences in acceptance rates were due not only to differences in cognitive style but also to differences in this subject population. From this and many other investigations [34, 74, 77, 79, 101, 151, 166, 174, 229, 252, 253, 263, 267, 268, 311, 330, 369] it appears that appropriate consideration of the human behavioral variable of cognitive style is very necessary for successful design of decision support systems.

A number of studies such as those by Taylor [369], Craik [67], Payne [272], Schneider and Shiffrin [313, 327], and Simon [342], indicate, as we will discuss in later sections, that human decisionmakers attempt to bring order into their information processing activities when confronted with excess information or the lack of sufficient information. Many early studies assumed that static fixed patterns of dealing with information were "preferred" by the decisionmaker for the process of experiencing the world;

and these were referred to as "cognitive style". Some early studies view cognitive style as a mode of functioning that is static and pervasive throughout a person's perceptive and intellectual activities. A number of intellectual processes are subsumed within the term cognitive style. These concern the way in which information is acquired or formulated, analyzed, and interpreted. Thus, cognitive style includes such human activities as information filtering and pattern recognition.

Zmud has indicated [414, 415] that those individual differences which influence information system success most strongly involve cognitive style, personality, and demographic/situational variables. Cognitive style refers to the process behavior that individuals exhibit in the formulation or acquisition, analysis, and interpretation of information; or data of presumed value for decisionmaking. Doubtlessly cognitive style is somewhat influenced by such personality variables as dogmatism, introversion, extroversion, and tolerance for ambiguity. However, little appears known concerning these influences. Gough discusses personality and personality assessment in his chapter in [87]; but it is rare to find, with some notable exceptions [249-251, 302, 331, 398], discussions of personality effects upon decisionmaking behavior in cognition studies. The demographic/situational variables involve personal characteristics such as intellectual ability, education, experience with and knowledge of specific contingency tasks, age, and the like. An important situational variable is the level of

stress encountered by the decisionmaker in a specific problem situation. The level of stress, which results in the adoption of a coping pattern, influences the decisionmaker's ability in acquisition and processing of the information necessary for decisionmaking. The subject of stress will be dealt with in some detail in Section 5. Many variables are especially important for an information processing model of cognitive behavior. Some will be discussed in Section 3. Our efforts in this section will be devoted primarily, therefore, to cognitive style concepts, especially the role of personality variables in the adoption of a cognitive style.

There are a number of cognitive style models in addition to that of Mason and Mitroff. Bariff and Lusk [24], for example, have discussed three cognitive style characteristics relevant to information system design: cognitive complexity, field dependent/independent, and systematic/heuristic. The cognitive complexity characteristic involves three structural characteristics of thinking and perception: differentiation, the number of dimensions sought or extracted and assimilated from data discrimination; the fineness of the articulation process in which stimuli are assigned to the same or different categories; and integration, the number and completeness of interconnections among rules for combining information.

Benbasat and Taylor [35] note that much cognitive complexity research deals with inter-personal perception and has limited value for modelling activities of managers in

processing information and making decisions. Mischel is especially perceptive in discussing the potential hazards of attributions and enduring categorizations of people into fixed slots on the basis of a few behavioral signs in his study of the interface between cognition and personality [251]. The assumptions that static characterizations are sufficiently informative to enable behavior predictions in specific settings are strongly challenged. An evaluation of the uses and limitations of static trait characterization of individuals is presented and the strong interacting role of context is emphasized. Mischel is especially concerned with "cognitive economics", that is to say the recognition that people are easily overloaded with an abundance of information and that simplified methods of acquisition and processing of information are, therefore, used. He is especially concerned also with growth of self-knowledge and rules for self-regulation with maturation, topics to be discussed in Section 5. We concur with these views in that we believe that it is the individual's experience with the task at hand that is the primary determinant of cognitive style. Further we believe that it is an individual's information processing capacity under various levels of stress, and in different contingency task structures that determines, in part, the quality of decisionmaking. These factors depend, strongly, upon experience. Thus we support the information processing view of Simon [337-344] that few characteristics of the human information processing system are invariant over the decisionmaker and the task. These characteristics are generally experiential and evolve over time in a dynamic fashion. They are not static and can not be treated as static and task invariant for a given individual.

In the Bariff and Lusk cognitive style model [24], individuals may be categorized according to whether they are tightly bound by external referrents in structuring cognitions, in which case they are called field dependent or low analytic; or whether they can make use of internal referrents as well as external referrents in structuring cognitions, in which case they are high analytic or field independent. In a field dependent mode, perception is dominated by the overall organization of the field. There is limited ability to perceive discrete parts of a field, especially as distinct from a specific organized background. Field independent people have more analytical and structuring abilities in comparison to field dependent people in that they can disaggregate a whole into its component parts.

The systematic-heuristic categorization of Bariff and Lusk describes cognitive styles associated with people who either search information for causal relationships that promote algorithmic solutions, or who search information by trial and error hypothesis testing. Systematic individuals utilize abstract logical models and processes in their cognition efforts. Heuristic individuals utilize common sense, past experience, and intuitive "feel". Systematic individuals would be able to cope with well-structure problems without difficulty,and would approach unstructured problems by attempting to seek underlying structural relations; whereas heuristic individuals would attempt to cope with unstructured problems without a conscious effort to seek structural identification.

Of particular importance with respect to cognitive styles are relationships between the environmental complexity of the contingency task structure and information processing characteristics. A number of authors have attempted experiments based on the hypothesis that the conceptual structure of the individual determines information processing characteristics. Conceptual structure is typically measured on a dimension of abstract vs. concrete. Abstract individuals would be capable of using integratively more complex conceptual processes than concrete type individuals. Abstractness may be characterized by the ability to differentiate a greater variety of information and to discriminate and integrate information in complex ways. Abstract individuals would, therefore, be expected to base actions on more information and to develop more complex strategies for information evaluation than concrete individuals. This is somewhat similar to Piaget's account of evolving cognitive development,* in that the "formal" thinker is capable of abstract thought, whereas the "concrete" thinker relies more on preceptual experience as a basis for thought and problem solution. While the work of Piaget appears to assume that cognitive capacity evolves over time, some research involving personality and cognitive style assumes that an individual's cognitive style is not task dependent and not subject to change as a function of contingency variables, such as experience.

*See Section 5 of this paper.

Among other efforts, Driver and Mock [83] developed decision style theory, a set of four decision styles based upon the heuristic-analytic characterization of Huysman [172], to relate conceptual structure of decisionmakers to both the amount of information they tend to use and the degree of focusing, that they exhibit in the use of information. A heuristic person will use intuition, past experience, concrete thought, and a wholistic approach to reach decisions. An analytic person will utilize abstract logical models and will search for causal relationships and underlying structure to evolve rationale for decisionmaking. The four decision styles are determined by the degree of focus in the use of information and the amount of information desired. A decisive person is one who wishes to see the minimum possible amount of information and who will likely identify a single workable decision. Decision speed obtained from short summary, often verbal, reports, is a characteristic of the decisive person. A flexible person is one who utilizes minimum information but who will identify a number of potentially acceptable decisions. A hierarchic person is one who utilizes much information, often obtained in a thorough way from long involved precise reports, to identify a single acceptable decision. An integrative person utilizes much information to identify a number of potentially acceptable decisions.

Vasarhelyi [389] has also examined the analytic-heuristic dimension. His experimental results indicate generally that analytic type people tend to use computers and other analytic

tools more in planning than do heuristic types. Heuristic types use less information than the analytic types and are more concerned with the lack of flexibility in computers than analytic types. However, his study of correlations among various style-measuring instruments indicates that these are relatively low.

Driver and Mock also suggested a fifth style which they referred to as the complex style, which is characterized by a wide search and analysis of information. It is a mixture of the integrative and hierarchic types. Zmud [415] has performed some experimental studies of this decision style theory. His findings indicate that perceptual differences can indeed be observed for specific cognitive styles and among subjects with different educational and experiential backgrounds. However, his results also indicate that there is no apparent relationship between cognitive style perceptions and actual cognitive behavior,despite consistent differences in perceptions of cognitive styles.

McKenney and Keen [242] have done extensive work on cognitive style measurements. These have become, in part, the basis for several definitive efforts [192, 193, 258] in decision support system design. They conceptualize cognitive style in two dimensions: information acquisition, and information processing and evaluation. The information acquisition mode consists of receptive and preceptive behavior, both at the opposite extremes of a continuum. They claim that preceptive decisionmakers use concepts, or precepts, to filter data, to focus on patterns of information, and to look for deviations

from or conformities with their expectations. Receptive people tend to focus on detail rather than patterns and derive implications from data by direct observation of it, rather than by fitting it to their own precepts.

With respect to information processing and evaluation, McKenney and Keen measured individuals on a scale, with the systematic thinker at one extreme and the intuitive thinker at the other extreme. They have shown, using a battery of pencil and paper tests, that systematic thinkers approach a problem by structuring it in terms of some method which would lead to a solution, whereas intuitive thinkers use trial and error, intuition, and previous experience to obtain solutions.

We have examined four cognitive style characterizations in this section. Table 2.1 summarizes the models of cognitive style that result from these efforts. We note the considerable similarity among these four constructs. There have been a number of studies of the measuring instruments involved in classifying people according to these cognitive styles. Many, such as the study by Vasarhelyi [389] mentioned previously, have found rather low correlations among test instruments. Zmud [413, 415] has indicated low correlation also among test scores on different instruments indicating cognitive styles. Chervany, Senn, and Dickson [57, 76] have expressed much concern and pessimism concerning the validity of much of the contemporary research in this area. They comment that the study of individual

TABLE 2.1 FOUR MODELS OF COGNITIVE STYLE

BARIFF AND LUSK [24]

COGNITIVE COMPLEXITY

- DIFFERENTIATION
- DISCRIMINATION
- INTEGRATION

FIELD INDEPENDENT/DEPENDENT
SYSTEMATIC/HEURISTIC

DRIVER AND MOCK [83]

DEGREE OF FOCUS IN USE OF INFORMATION

- MULTIPLE SOLUTIONS IDENTIFIED
- ONE SOLUTION IDENTIFIED

AMOUNT OF INFORMATION USED

- MAXIMUM
- MINIMUM

MCKEENEY AND KEEN [242]

INFORMATION ACQUISITION

- RECEPTIVE
- PRECEPTIVE

INFORMATION EVALUATION AND INTERPRETATION

- SYSTEMATIC
- INTUITIVE

MASON AND MITROFF [238]

INFORMATION ACQUISITION

- INTUITIVE
- SENSING

INFORMATION EVALUATION AND INTERPRETATION

- THINKING
- FEELING

personality differences,as predictors of human behavior and performance,have been basically unsuccessful in that it has not been possible to predict performance on the basis of personality characteristics. Their comment, and the comments of others, that the characteristics of the task in which the individual involved is a prime determinant of human behavior, appears unassailable. We will provide and discuss additional evidence supporting a dynamic cognitive style characterization that will incorporate the contingency task structure and the decisionmakers task experience in several other sections of this paper. In particular we emphasize the strong need for consideration of the structure and the content of planning and decision situations in order to evolve contextually meaningful support.

3. Information Processing

Problem solving, judgment, and decisionmaking imply both thought and action. Hence, decisionmaking can be defined as the processes of thought and action involving an irrevocable allocation of resources that culminates in choice behavior. In making a decision, more often than not, the decisionmaker is dealing with environments characterized by risks, hazards, uncertainty, complexity, changes over time, and conflict. Further, the quality of a decision depends upon how well the decisionmaker is able to acquire information, to analyze information, and to evaluate and interpret information such as to discriminate between relevant and irrelevant bits of data. Decision quality also depends upon how well the decisionmaker is able to cope with stress, which is invariably encountered in important decision circumstances. Effective management of these factors enables strategies by which the decisionmaker may arrive at a good problem solution, decision, or judgment.

A number of studies such as those by Barron [28]; Bettman [37]; Chorba and New [58]; Delaney and Wallsten [73]; Feather [107]; Howell and Fleishman [165]; Huber, O. [168]; Huber, G. [170, 171]; Ives, Hamilton and Davis [174]; Libby and Lewis [215]; Lucas and Nielson [228]; MacCrimmon and Taylor [232]; Montgomery and Svenson [256]; Moskowitz, Schaefer, and Borcherding [259]; Payne [275]; Simon [342]; Tushman and Nadler [379]; Tuggle and Gerwin [380]; Wallsten [395, 396]; and Wright [402-406]; discuss the vital

role of human information processing in decisionmaking. Most contemporary researchers regard information processing as a crucial task for effective decisionmaking and state that the type of decision problem, the nature of the decision environment, and the current state of the decisionmaker, combine to determine decision style and decision strategy for a specific task. The term information processing refers to the processing of verbal reports as well as quantitative data since verbal reports are data [99].

An information processing theory of problem solving, judgment, and decision making is based on the assumption that individuals have an input mechanism for acquisition of information; an output mechanism for interpretation and choicemaking; internal processes for filtering and other analysis efforts associated with information; and memories for long and short term storage of information. There are a large number of ways of representing human information processing. Many of these are described in texts in cognitive psychology such as Anderson [7]; Posner [281]; or Solso [354], and in works in consumer choice such as Bettman [37]. Much of the work in this area owes a great deal to Simon [334-344] who has developed information processing theories in psychology and in artificial intelligence.

Figure 3.1 presents a conceptual model of a systems engineering framework [308] for human information processing. There are doubtlessly a number of components missing from this model. It does not show, for example, the essentially iterative nature of the process. Nevertheless we feel that it provides a useful point of departure and a structure for our efforts to follow.

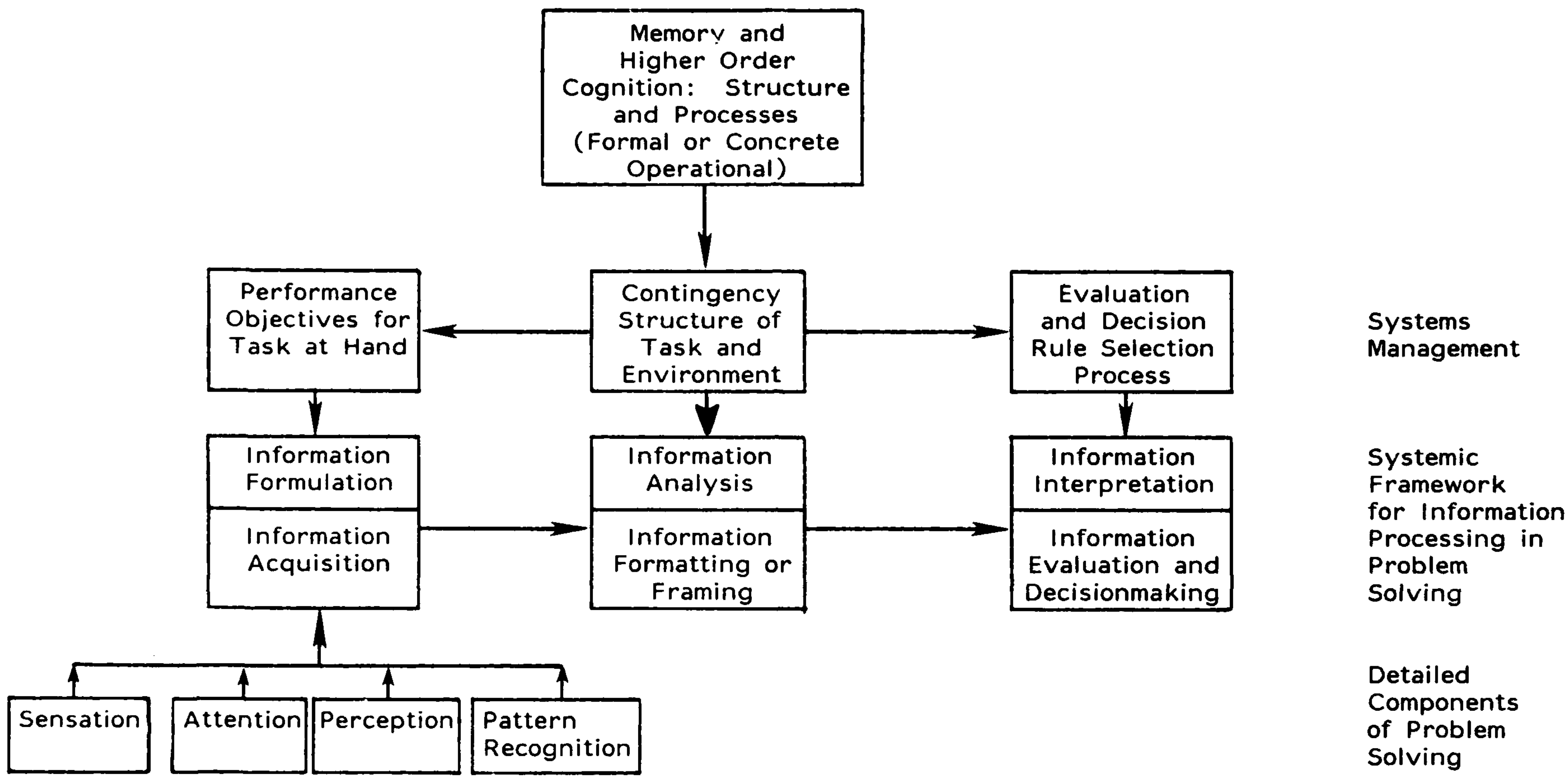


Figure 3.1 A Systems Engineering Conceptual Model of Human Information Processing

The key functions, which determine how a specific problem or decision situation is cognized, depend upon an interaction of the memory and higher order cognition of the problem solver with the environment through the contingency task structure. We will be very concerned with development of a conceptual model of higher order cognition and the contingency task structure in Section 5. It is appropriate to remark here that the various information analysis and interpretation processes of thinking, task performance objective identification, evaluation and decision rule identification, are called "higher order" cognition. This is not because they are somehow more important than the so called "lower order" cognition efforts of information acquisition involving formulation: sensation, attention, perception, and pattern recognition; but because they occur later in time in the overall information processing effort.

It is important to note that information processing and decision making efforts intimately involve memory. Memory [102] influences human judgment in a number of ways. It will influence the perception of the contingency task structure associated with an issue as well as the decision rules used for evaluation of alternatives. Two characteristics of human memory are of special importance for our efforts here. First, information will be encoded in more or less efficient and effective ways in terms of human abilities for recall. The coding process is dependent, also, upon the interpretation attached to information and this strongly influences event recall, perceptions, and associated cognitive

biases. The literature concerned with memory and its components, and their relations and interaction with human perceptual experience and behavior, is vast and speculative in nature. There have been many studies, both physiological and psychological, concerned with the identification of the memory "engram", which is hypothesized to be the fundamental unit of memory. We need not be especially concerned, in this effort, with the various physiological structures and processes associated with human memory; or with various related behavior therapies [109]; however the essentials are reviewed below briefly. A useful brief survey of the literature on memory is presented by Thomassen and Kempen in Chapter 3, Vol. II of [244], by Fox [128], and by Radcliff [284].

Human memory constitutes two major components, short term memory and long term memory. Short term memory plays a key role in immediate recall of actively rehearsed limited information [7, 354]. Unless conscious effort is put forth in recalling information from short term memory, this cannot be done after a lapse of 30 to 60 seconds from initial presentation. Models of a working short term memory involve a number of mechanisms, such as an articulatory rehearsal loop that has the capacity to retain short verbal sequences. This is just one mechanism by which short term retention is possible. There are a number of other sensory registers. It is important to note that short term memory is an integrated network of many mechanisms, and is associated, in use, with a number of skilled processes.

Shiffrin & Schneider [313,327] incorporate concepts of attention, memory, and perceptual learning in their theory of short term retention. They hypothesize short term storage, the function of which is active control of thinking, reasoning, and general memory processes. According to Shiffrin & Schneider, short term storage is an activated subset of long term storage. Transfer of information from short term storage to long term storage is dependent on attentional limitations, interference from strong external and internal stimuli, extent of analysis of information, and formation of associations in long term storage. There have been many studies involving concepts such as retrieval processes, memory trace identification, encoding processes, and recognition which we will not discuss as they appear of secondary importance to the goals of this particular effort. While five to seven unconnected items is believed to be the maximum amount of information that can be retained in short term memory, long term memory may contain a virtually limitless amount of information.

The factors which govern selection of performance objectives for an information processing task are based primarily upon situational factors, such as motivation of the problem solver and the level of stress associated with the task. Section 5 will be devoted to a discussion of a conflict model determinant of the contingency task structure which governs performance objective selection.

Our effort in the remainder of this section will be devoted to a description of the various processes which support information acquisition and information analysis. We will also discuss some of the cognitive biases that can result from "poor" information acquisition and information analysis. Information

interpretation, which leads to alternative evaluation and decision-making, is an important and somewhat distinct part of the overall information processing model. It will be discussed in the next four sections from several perspectives.

The types of operations involved in information acquisition are sensation, attention, perception, and pattern recognition. Doubtlessly there are other valid ways of categorizing these operations [7,37,67,100,137, 148,175,281,297,298,313,327,333] but the taxonomy used here is sufficient for our purposes. In sensation, information is acquired through the five major sense modalities, which are environmentally activated, in response to a specific array of stimulus energies. In a specific decisionmaking situation, the decisionmaker filters out bits of data believed to be irrelevant. The filtering process is based upon task characteristics, experience, motivation, as well as other features and demands of the specific decision-making situation. If such a filtering mechanism were not to exist, the decisionmaker would often encounter information overload which generally results in saturation and the inability to process sufficient information for the task at hand. Short-term and long-term memory components play key roles in the information acquisition process as the decisionmaker proceeds with efforts that culminate in choice. A response system couples the memory system to the sensory system and the environment. Thus it controls or activates the sensory modalities on the basis of the actions taken. Through the response system we close the information flow feedback loop. Bower, in volume 1 of Estes [100], has summarized principal components of the flow system. A model of the principal components of information

flow might consist of: the response system, the sensory system, the memory system, and the central processor. The central processor coordinates memorizing, thinking, evaluation of information, and final decisionmaking.

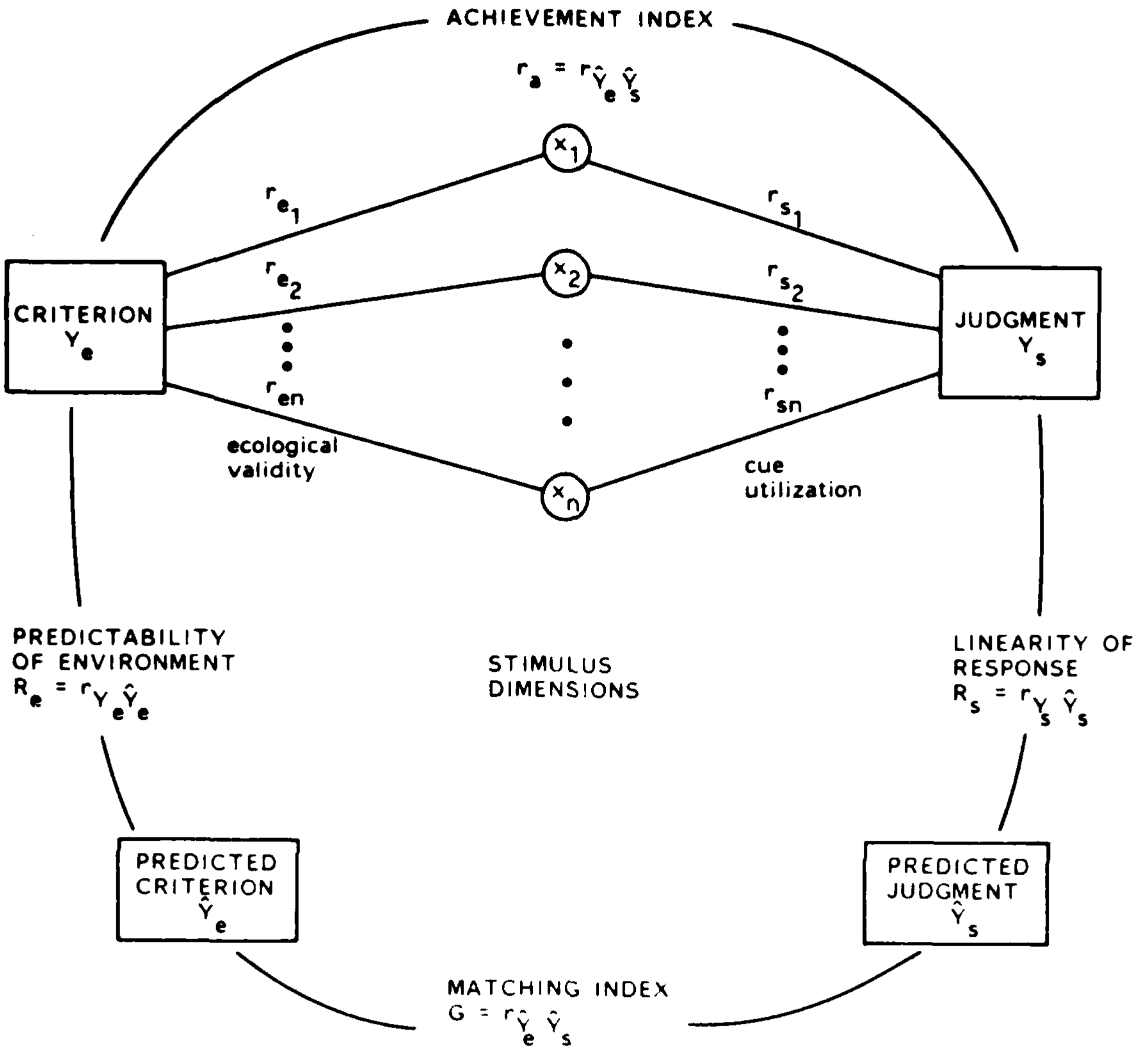
Ultimately involved in retention processes is the notion of attention [7]. In order for information to be transferred from short term memory to long term memory, constant conscious attention, in terms of rehearsal, is required. Information entering short term memory that is not attended to, through specific conscious processes, is lost. Processing of information demands attending to relevant bits of incoming data and transfer of the data into long term memory for future retrieval for making a decision. Interferences of various types may interrupt attention and thus hinder transfer and retention of relevant stimuli into long-term memory.

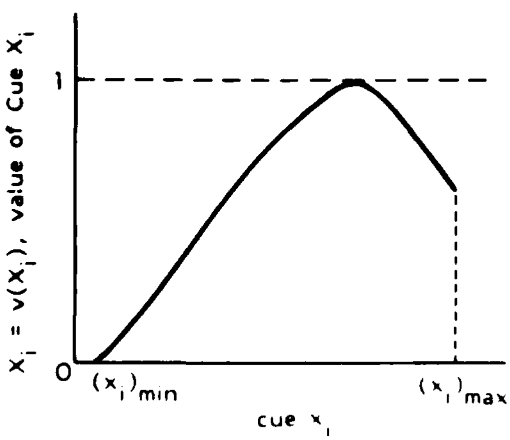
Inherent in the processing of information acquisition, is the process of pattern recognition. This process generally involves two phases: extraction, and identification. A given stimulus is "coded" in terms of its features. These extracted features of the object or stimulus describe the stimulus. The term "features" implies such characteristics as angles, lines, or edges. A stimulus may be received through any of the sense modalities. The meaning that this conveys to the decisionmaker, or the manner in which the decisionmaker perceives the stimulus, is dependent upon the patterns extracted from the stimulus. In the identification phase, the sensory-perceptual system classifies the stimulus object. The way in which this is often assumed to

occur is by a weighted matching of the current feature list against a likely set of prototypes in long-term memory [7, 313, 327, 354] with the input being classified according to the name of the best matching prototype. The quality or extent of the sensory information extracted determines the accuracy of identification. Pattern recognition processes are thus seen to involve components of memory: long term memory, short term memory, and working memory.

We have just described what might be regarded as a component, or physiological,model of information processing. In these stimulus response approaches,behavior is seen as being initiated by the onset of stimuli. A seeming deficiency in approaches of this sort is that there is little consideration of how information bits are aggregated to influence choice;and how the decision-maker goes about the process of information formulation or acquisition, analysis, and interpretation.

A lens model "developed by Brunswick and his students is a notable exception to this. The Brunswick lens model is the basis for the policy capture or social judgment theory approach of Hammond and his colleagues [140-143]. The lens model, displayed in Figure 3.2, assumes that people are guided by rational programs in their attempt to adapt to the environment. There is a criterion value, Y_e, and the subjects response, judgment, or inference, Y_s. The left side of Figure 3.2 represents ecological cue validities which are the correlations r_{ei} between the cues and the criterion value. On the right or organismic side of Figure 3.2, a subject will base a





$$\hat{Y}_e = \sum_{i=1}^{n} h_{ei} v(x_i) = \sum_{i=1}^{n} h_{ei} X_i$$

$$r_{ei} = var(Y_e X_i)$$

Figure 3.2 The Brunswick Lens Model and its Relation to Hammond's Social Judgment Theory

response, judgment, or inference, Y_s, on the perceived ecological structure. By calculating the correlations, r_{si}, that exist between the cues and the response or criterion evaluation, learning concerning the response system can be obtained.

We note that the value of the environmental criterion Y_e and the subject inference Y_s are directly comparable if linear combinations of the cues are assumed. We have, for n cues,

$$Y_e = \sum_{i=1}^{n} h_{ei} x_i + \nu_e, \qquad \hat{Y}_e = \sum_{i=1}^{n} h_{ei} x_i$$

$$Y_s = \sum_{i=1}^{n} h_{si} x_i + \nu_s, \qquad \hat{Y}_s = \sum_{i=1}^{n} h_{si} x_i$$

where h_{ei} and h_{si} are optimum regression weights for the independent cues x_i which provide measures of the importance weights of the cues, ν_e and ν_s are error terms due to inadequacy of the linear model, Y_e and Y_s are the true criterion value and subject response, and $\hat{Y}_e$ and $\hat{Y}_s$ are the predicted criterion value and subject response based on the observed cues. The many works of Hammond and his associates [2, 21, 45, 54, 140-143, 186, 187, 261, 290, 294, 295, 404] concerning social judgment theory make use of this lens model. The approach has been shown to be useful in a variety of areas such as policy formulation, negotiation, and conflict resolution. Recent efforts by Hoffman, Earle, and Slovic [154] have shown that the computer displays of social judgment theory: which show both task characteristics, in terms of cue values and corresponding criterion values: and response characteristics, in terms of

individual cue values and associated subject responses and judgments; provide a very effective feedback mechanism which might enable people to effectively learn much about complex functional relationships and tasks. There are a number of studies of regression analysis approaches to determination of parameters for decision rules [260, 290]. Use of regression analysis is central to social judgment theory. Recent applications of the approach [261] have involved using simulation models to generate responses which are valuated by the decisionmaker.

Questions concerning the cognitive style used by the decisionmaker are, we believe, very important. Information analysis and information interpretation may be accomplished in a concrete operational mode of thought or in a formal operational mode. We will describe the essential features of these two higher level cognition processes in Section 5. The concrete operational thought process, which is typically applied in familiar situations which people perceive to be well structured, may involve efforts such as reasoning by analogy, or affect, or standard operating procedures. The formal operational thought process, typically applied in situations with which the problem solver is unfamiliar and inexperienced, may involve explicit use of quantitative or qualitative analytical thought.

In either of these modes or "styles" of thought or cognition, information acquisition, analysis, and interpretation may be quite flawed. Many recent studies emphasize the strong need for modeling problem solving behavior in a descriptive, or positive, sense in order to detect possible flaws in information processing. Our discussions thus far in this section have been concerned with

physiological models in which people have input and output mechanisms, a memory for information storage and retrieval, and a central processor for coordination and control. Here, we wish especially to underscore the need not only for physiological, or stimulus-response, models but especially for process tracing [72, 95-98, 255] models of information formulation, analysis, and interpretation as well as associated decisionmaking. Knowledge of the actual unaided process of problem solving,or descriptive process tracing,should serve as a useful guide to the design of information systems that avoid, or at least ameliorate the effects of, cognitive heuristics and biases. This involves requirements for a knowledge of the ways in which people apply strategies in order to reach judgments.

A large number of contemporary studies in cognitive psychology indicate that the attempts of people, including experts, to apply various intuitive strategies in order to acquire and analyze information for purposes such as prediction, forecasting, and planning, are often flawed. Many studies have been conducted to describe and explain the way information is acquired and analyzed and the results of faulty acquisition and analysis. Generally the descriptive behavior of subjects in tasks involving information acquisition and analysis is compared to the normative results that would prevail if people followed an "optimal" procedure. There have been a number of recent discussions, from several perspectives,

of cognitive biases [61,62,98,142,154,156,160,161,185,234,263,304,309, 346-349,351,352,385,386,406-408]. The recent texts by Nisbett and Ross [264] and Hogarth [159] concerning the strategies and biases associated with judgment and choice are especially noteworthy. Among the cognitive biases that have been identified are several which affect information formulation or acquisition, information analysis, and interpretation. Among these biases, which are not independent, are:

(1) Adjustment and Anchoring [345, 383] - Often a person finds that difficulty in problem solving is due not to the lack of data and information; but rather to the existence of excess data and information. In such situations, the person often resorts to heuristics which may reduce the mental efforts required to arrive at a solution. In using the anchoring and adjustment heuristic when confronted with a large amount of data, the person selects a particular datum, such as the mean, as an initial or starting point, or anchor, and then adjusts that value improperly in order to incorporate the rest of the data such as to result in flawed information.

(2) Availability [383, 385] - The decision maker uses only easily available information and ignores not easily available sources of significant information. An event is believed to occur frequently, that is with high probability, if it is easy to recall similar events.

(3) Base Rate[25,291,386] - The likelihood of occurrence of two events is often compared by contrasting the number of times the two events occur and ignoring the rate of occurrence of each event. This bias often occurs when the decisionmaker has concrete experience with one event but only statistical or abstract information on the other. Generally abstract information will be ignored at the expense of concrete information. A base rate determined primarily from concrete information may be called a causal base rate whereas that determined from abstract information is an incidental base rate. When information updates occur, this individuating information often is given much more weight than it deserves. It is much easier for individuating information to over-ride incidental base rates than causal base rates.

(4) Conservatism [210, 259, 345] - The failure to revise estimates as much as they should be revised, based on receipt of new significant information, is known as conservatism. This is related to data saturation and regression effects biases.

(5) Data Presentation Context [161] - The impact of summarized data, for example, may be much greater than that of the same data presented in detail, nonsummarized form. Also different scales may be used to considerably change the impact of the same data.

(6) Data Saturation - People often reach premature conclusions on the basis of too small a sample of information while

ignoring the rest of the data that is received later on, or stopping acquisition of data prematurely.

(7) Desire for Self Fulfilling Prophecies - The decisionmaker values a certain outcome, interpretation, or conclusion and acquires and analyzes only information that supports this conclusion. This is another form of selective perception.

(8) Ease of Recall [205, 382, 383] - Data which can easily be recalled or assessed will affect perception of the likelihood of similar events occurring again. People typically weigh easily recalled data more in decisionmaking than those data which cannot easily be recalled.

(9) Expectations [161, 235] - People often remember and attach higher validity to information which confirms their previously held beliefs and expectations than they do to disconfirming information. Thus the presence of large amounts of information makes it easier for one to selectively ignore disconfirming information such as to reach any conclusion and thereby prove anything that one desires to prove.

(10) Fact-Value Confusion - Strongly held values may often be regarded and presented as facts. That type of information is sought which confirms or lends credibility to one views and values. Information which contradicts one's views or values is ignored. This is related to wishful thinking in that both are forms of selective perception.

(11) Fundamental Attribution Error (Success/Failure error) [263, 264] - The decisionmaker associates success with personal inherent ability and associates failure with poor luck in chance events. This is related to availability and representativeness.

(12) Gamblers Fallacy - The decisionmaker falsely assumes that unexpected occurrence of a "run" of some events enhances the probability of occurrence of an event that has not occurred.

(13) Habit - Familiarity with a particular rule for solving a problem may result in reutilization of the same procedure and selection of the same alternative when confronted with a similar type of problem and similar information. We choose an alternative because it has previously been acceptable for a perceived similar purpose or because of superstition.

(14) Hindsight [112- 114, 116] - People are often unable to think objectively if they receive information that an outcome has occurred and they are told to ignore this information.

(15) Illusion of Control [209, 210] - A good outcome in a chance situation may well have resulted from a poor decision. The decisionmaker may assume a feeling of control over events that is not reasonable.

(16) Illusion of Correlation [115, 383] - A mistaken belief that two events covary when they do not covary is known as the illusion of correlation.

(17) Law of Small Numbers [See Kahneman and Tversky in 235] - People are insufficiently sensitive to quality of evidence. They often express greater confidence in predictions based on small samples of data with nondisconfirming evidence than in much larger samples with minor disconfirming evidence. Sample size and reliability often have little influence on confidence.

(18) Order Effects [161, 184] - The order in which information is presented affects information retention in memory. Typically the first piece of information presented (primacy effect) and the last presented (recency effect) assume undue importance in the mind of the decisionmaker.

(19) Outcome Irrelevant Learning System [96, 97] - Use of an inferior processing or decision rule can lead to poor results; and the decisionmaker can believe that these are good because of inability to evaluate the impacts of the choices not selected and the hypotheses not tested.

(20) Overconfidence [114, 183,216] - People generally ascribe more credibility to data than is warranted and hence overestimate the probability of success merely due to the presence of an abundance of data. The greater the amount of data, the more confident the person is in the accuracy of the data.

(21) Redundancy - The more redundancy in the data, the more confidence people often have in their predictions, although this overconfidence is usually unwarranted.

(22) Reference Effect [30, 383] - People normally perceive and evaluate stimuli in accordance with their present and past experiential level for the stimuli. They sense a reference level in accordance with past experience. Thus reactions to stimuli, such as a comment from an associate, are interpreted favorably or unfavorably in accordance with our previous expectations and experiences. A reference point defines an operating point in the space of outcomes. Changes in perceptions, due to changes in the reference point, are called reference effects. These changes may not be based upon proper, statistically relevant computations.

(23) Regression Effects [183, 383] - The largest observed values of observations are used without regressing towards the mean to consider the effects of noisy measurements . In effect, this ignores uncertainties.

(24) Representativeness [382, 383] - When making inference from data, too much weight is given to results of small samples. As sample size is increased, the results of small samples are taken to be representative of the larger population. The "laws" of representativeness differ considerably from the laws of probability and violations of the conjunction rule, $P(A \cap B) \leq P(A)$, are often observed.

(25) Selective Perceptions [161] - People often seek only information that confirms their views and values. They disregard or ignore disconfirming evidence. Issues are structured on the basis of personal experience and wishful thinking. There are many illus-

trations of selective perception. One is "reading between the lines" such as, for example, to deny antecedent statements and, as a consequence, accept "if you don't promote me, I won't preform well" as following inferentially from " I will perform well if you promote me."

(26) Spurious Cues [161] - Often cues appear only by occurrence of a low probability event but they are accepted by the decisionmaker as commonly occurring.

(27) Wishful Thinking - The preference of the decisionmaker for particular outcomes and particular decisions can lead the decisionmaker to choose an alternative that the decisionmaker would like to have associated with a desirable outcome. This implies a confounding of facts and values and is a form of selective perception.

Doubtlessly there are other information acquisition, analysis, and interpretation biases that we have not identified here. Any categorization into acquisition, analysis, and interpretation bias is somewhat arbitrary since iteration and feedback will often, in practice, not allow this separation. Also, many of the identified biases overlap in meaning and, therefore, are related to others. Some further discussion of cognitive biases will be presented in our discussion of the situation framing phase of prospect theory in Section 3. Certainty, reflection, and isolation effects are three results of these biases that have particular prominence in prospect theory.

Of particular interest are circumstances under which these biases occur; their effects on activities such as decisionmaking, issue resolution, planning, and forecasting and assessment; and appropriate styles which might result in debiasing or amelioration of the effects of cognitive bias.

Many of the cognitive biases that have been found to exist have been found in the unfamiliar surroundings of the experimental laboratory, and generalization of this work to real world situations is a contemporary research area of much interest. However most of the laboratory experiments have concerned very simple, if unfamiliar tasks. A number of studies have compared expert performance with

simple quantitative models for decisionmaking; such as those by Brehmer [47]; Cohen [62]; Dawes and Corrigan [70]; Dawes [71]; Goldsmith [132]; Kleinmuntz and Kleinmuntz [204]; and by several authors in Wallstein's recent definitive work concerning cognitive processes in choice and decision behavior [396]. While there is controversy [63,349], most studies have shown that simple quantitative models perform better in human judgment and decisionmaking tasks, including information processing, than wholistic expert performance in similar tasks. This would appear to have major implications and to sound major caveats for such areas as "expert forecasting". This caution is strongly emphasized in the works of Hogarth and Makridakis [161]; Makridakis and Wheelright [235]; and Armstrong [14-16]. This is a caution noted in but a few [18] of the contemporary works on forecasting and assessment.

There are a number of prescriptions which might be given to encourage avoidance of possible cognitive biases and to debias those that do occur [96,98, 161, 184, 235, 355, 386]. Some suggestions to avoid cognitive bias are:

(1) Sample information from a broad data base and be especially careful to include data bases which might contain disconfirming information.

(2) Include sample size, confidence intervals, and other measures of information validity in addition to mean values.

(3) Encourage use of models and quantitative aids to improve upon information analysis through proper aggregation of acquired information.

(4) Avoid the hindsight bias by providing access to information at critical past times.

(5) Encourage decisionmakers to distinguish good and bad decisions from good and bad outcomes in order to avoid various forms of selective perception such as, for example, the illusion of control.

(6) Encourage effective learning from experience. Encourage understanding of the decision situation, and methods and rules used in practice to process information and make decisions, such as to avoid outcome irrelevant learning systems.

(7) Use structured frameworks based on logical reasoning [255, 376] in order to avoid confusing facts and values, and wishful thinking; and to assist in processing information updates.

(8) Both qualitative and quantitative data should be collected, and all data should be regarded with "appropriate" emphasis. None of the data should be over weighted or underweighted in accordance with personal views, beliefs, or values only.

(9) People should be reminded, from time to time, concerning what type or size of sample from which data are being gathered, so as to avoid the representativeness bias.

(10) Information should be presented in several orderings so as to avoid recency and primacy order effects, and the data presentation context and data saturation biases.

Kahneman and Tversky, in [235], discuss a systemic procedure to enhance debiasing of information processing activities. A definitive discussion of debiasing methods for hindsight and overconfidence is presented by Fischhoff in [185]. Lichtenstein and Fischhoff present a number of helpful guidelines to assist in training for calibration in [217]. Clearly, more efforts along these lines are needed. Studies to determine the extent to which learning feedback acquired through use of methods such as social judgment theory contributes to debiasing would be especially rewarding. This is especially the case since confidence in unaided judgment is learned and maintained through feedbadk even when there is very little or no justification for this confidence [94]. Typically, outcomes which follow from decisions based on negative judgments are not observed. Reinforcement of self fulfilling prophecy type judgments through positive outcome feedback only occur in spite of, rather than due to, judgment validity.

Research integrating the methods whereby people integrate or aggregate information and attribute causes [8-12,142,143,186,190,199, 321,364] with methods for the identification and amelioration of cognitive biases would be of interest and of much potential use, also.

In a sense, the results of this section are disturbing in that they tend to support the "intellectual cripple" hypothesis of Slovic [142, pg. 14], and to imply that humans may well be little more than masters of the art of self deception. On the other hand there is strong evidence that humans are very strongly motivated to understand, to cope with, and to improve themselves and the environment in which they function. While there are a number of fundamental limitations to systemic efforts to assist in bettering the quality of humans judgment, choice, and decision

making [307], there are also a number of desirable activities [161, 305, 385]. These can assist in increasing the relevance of systemic approaches such as those which result in information processing adjuvants for policy analysis, forecasting, planning, and other judgment and decision tasks in which information acquisition, analysis and interpretation play a needed and vital role.

4. Decision Rules

In order to select an alternative plan or course of action for ultimate implementation, the decisionmaker applies one or more decision rules which enable comparison prioritization, and ultimately, selection of a single policy alternative from among a set of choice alternatives. The purpose of a decision rule is to specify the most preferred alternative; generally from a partial or total ordering, or prioritization of alternatives. To utilize a decision rule we must have a set of alternatives, a set of objectives to be accomplished by the alternatives, a knowledge of the impacts of the alternatives, evaluation of these impacts, and associated preference information. Decision rules may be explicit or implicit in terms of the way in which they are used in the decision process.

We can assume, without loss of generality, that each single policy alternative may represent a complex portfolio of individual alternatives and that the set of choice alternatives contains mutually exclusive components. This formulation can always be accomplished but may result in a very large set of policy alternatives since n individual alternatives can be combined into 2^n possible portfolios of alternatives. Failure to consider combination of alternatives may result in significant errors in decision making unless each of the individual alternatives represents one component of a portfolio of all possible combinations of individual alternatives, or unless the individual alternatives are independent or mutually exclusive.

It is assumed, at the interpretation step of the decision process, that formulation and analysis have been accomplished such that there exists a decision situation structural model and the results of exercizing the model. Thus objectives, relevant constraints, some bounds on the issue, possible policy alternatives, impacts of policy alternatives, etc. are assumed known. The choice of a decision rule will depend, in large measure, upon the decision situation structural model as reflected in the contingency task structure. We will discuss dynamic models for contingency task structures in our next section.

The above discussion may appear representative primarily of the judgment and decision process associated with the formal operational thought model that we will elaborate upon in our next section. For purposes of clarity of exposition here, we have presented an oversimplified view of how decision rules are used to aggregate information and evaluate alternatives. The sequence we have described implies comparison and evaluation of alternatives only after we have first accomplished formulation and analysis of the issue under consideration. As we have noted throughout our discussion, decisionmakers typically compare and evaluate alternatives while they are in the process of decision situation formulation and analysis. These partial comparisons and evaluations lead to searches for additional policy alternatives, additional analysis, etc. As we have also noted, the entire decision process typically occurs in a parallel-simultaneous-iterative fashion rather than an exclusively sequential series of steps in which formulation is followed by analysis, which

is followed by interpretation.

Individuals and decision environments vary so greatly that there are a great number of decision rules that will be needed to describe actual decision situations. Schoemaker [315] is among a number of authors [121, 255, 364, 365, 372] who have attempted classification schemes to allow categorization of various descriptive decision rule models. His first level categorization separates decision rules into holistic and non-holistic categories. In a holistic decision rule each alternative, or portfolio of alternatives, is evaluated and assigned a value or utility. After all alternatives have been evaluated, they are compared and alternative A is said to be preferred to alternative B if its evaluation has given it a greater utility such that $U(A) > U(B)$. In nonholistic decision rules, individual alternatives, or portfolios of alternatives, are generally compared with one another in a sequential elimination process. This comparison may be against some standard, across a few attributes within alternative pairs; or across alternatives, with alternative attributes being compared one at a time.

Each of these categories appears to imply disaggregation, into components, of the event outcomes likely to follow from decisions. Our section on contingency task structure models will propose a dynamic evolving cognitive style model which admits of expert situational understanding that involves reasoning by analogy, intuitive affect, and other forms of non-verbal, almost unconscious, perception. We elect to call this type of reasoning wholistic and

add a third category to the classification scheme of Schoemaker.

Consequently, we envision three first level general categories of decision rules: holistic, heuristic, and wholistic. In a holistic decision rule, there is an attempt to consider all aspects of a decision situation in evaluating choices by means of disaggregation of various choice components. In a heuristic decision rule, detailed complicated comparisons are not used. Rather, simplified approximations to holistic decision rules are used. In a wholistic decision rule, the evaluation and choice of alternatives is based upon use of previous experience, hopefully true expertise, with respect to similar decision situations. The selection of an alternative is based upon its perceived or presumed worth as a whole and without detailed conscious consideration of the individual aspects of each alternative. It is possible to define a number of decision rules and categorize them. The first level categories we have defined are not mutually exclusive. A number of decision rules doubtlessly can be categorized into more than one of these first level decision categories. Figure 4.1 illustrates a possible inclusion structure for the decision rules we will describe here.

Expected utility theory. Our first decision rule is based on expected utility theory and is doubtlessly the most familiar decision rule to engineers. This rule derives from a "rational actor"* decision model [3,4,89,103,121,134,169,192,222,256,265,285,315,359,397] which is more fully discussed in Section 6.

The rational actor model is a normative model. Von Neuman and Morgenstern, who introduced the axioms of the model of rational man, stated the purpose of their work as: "... to find mathematically

*Technological or economic rationality would be a more appropriate term.

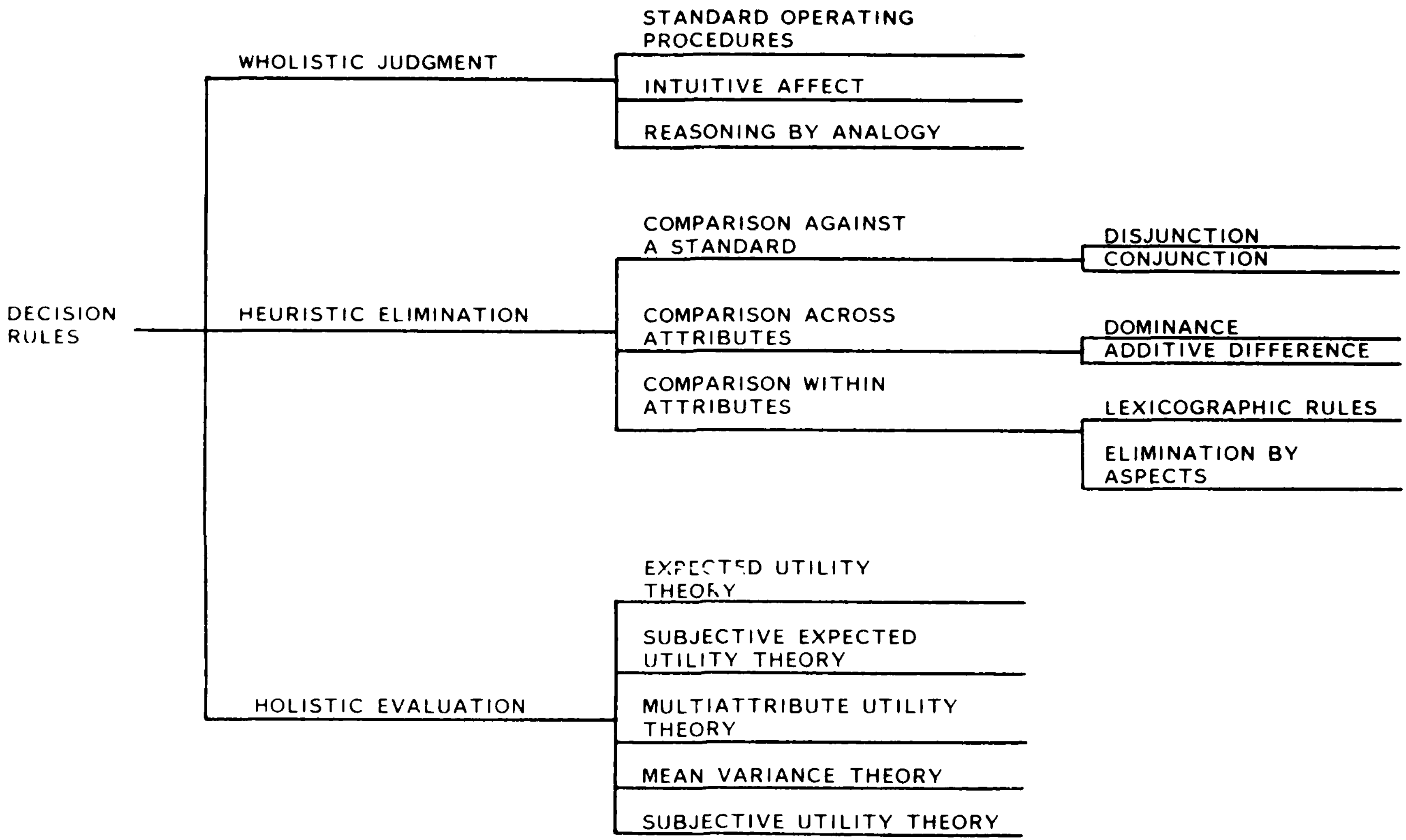


FIGURE 4.1 HIERARCHICAL STRUCTURE OF DECISION RULES

complete principles which define 'rational behavior' ... a set of rules for each participant which tell him how to behave in every situation which may conceivably arise."

The idea of rationality originated in the economics literature where microeconomic models of the consumer and the firm assumed complete information and rationality. The rational person is assumed to have identified a set of well-defined objectives and goals and is assumed to be able to express preferences between different states of affairs according to the degree of satisfaction of attaining these objectives and goals. A rational person has identified available alternative courses of action and the possible consequences of each alternative. The rational person makes a consistent choice of alternative actions in order to maximize the expected degree of satisfaction associated with attaining identified objectives and goals.

A number of elements are assumed to exist in the rational actor model:

(1) A set of policy alternatives, A;

(2) The set of possible consequerces of choice or future states of nature or decision outcomes, called S;

(3) A utility function $U(s)$ that is defined for all elements s of S;

(4) Information as to which outcomes will occur if a particular policy alternative a in A is chosen; and

(5) Information as to the probability of occurrence of any particular outcome if an alternative $a \epsilon A$ is chosen. $P_a(s)$ is the probability that $s \epsilon S$ will occur if $a \epsilon A$ is chosen.

There are a number of ways in which the axioms associated with the rational actor model may be stated. Each statement of the axioms allows proof of the fact that cardinal utility functions will exist and be unique only up to positive linear transformations. Further, the evaluation of expected utility allows choice making and prioritization of alternatives in accordance with the expected utility of each alternative. There are a number of textbook accounts of expected utility theory to which the interested reader of this review may turn for alternative sets of axioms and detailed accounts of the use of expected utility theory [51,163,196,222,285,302,315]. MacCrimmon and Larson interrelate the major axiom systems in expected utility theory in [3] in a noteworthy contribution to understanding of the several systems that lead to (essentially) the same results for the rational actor model.

The rational actor model is often accepted as a normative model of how decisions should be made, at least in a substantive or "as if" fashion. It is often observed that the model is not an accurate description of either the substance or the process of actual unaided choicemaking behavior. Some of these observers use empirical evidence of the deviation of actual decision-makers from either substantive rationality or process rationality.

These observations are doubtlessly correct. The rational actor model is, however, invaluable in that it can be often used as reference for comparison of actual behavior with ideal "aided" or normative behavior. Further, it provides a benchmark against which to compare simplified heuristics. Our efforts and discussions in this section concern primarily substantive behavior although we recognize the great difficulty, in practice, of separating substance from process.

Simon and his colleagues introduced the concept of bounded rationality and developed a satisficing model for individual choice making. It is worth noting that boundedly rational actors are basically rational subject to constraints on the formulation, analysis, and interpretation of information; and the substitution of achievement of a target level of return, or aspiration level, for selection of the best alternative. Typically, people satisfice by adaptive adjustment [72] of aspirations such that, in repetitive decision situations, optimizing behavior is approached [270].

There is absolutely nothing in the formulation of the rational actor model which requires identification of <u>all</u> objectives, <u>all</u> possible alternatives, <u>all</u> possible impacts of alternatives, etc. The rational actor model is perfectly capable of being used to allow prioritization and selection of the best alternative, by evaluating some impacts and with knowledge of some objectives, from among an incomplete set. It, in no sense, necessarily requires completeness in everything and the associated complexity that this would require. Actual decisionmaking behavior may not, however, even

be boundedly rational; but may employ such poor heuristics as to result in inferior choicemaking even to the extent of selecting inferior choices from among those in a bounded set.

There have been a number of experimental studies and field studies of the appropriateness of the expected utility model [3, 111, 117, 119, 125, 184-186, 237, 336-341, 385] as a descriptive model of substantive unaided behavior. Among the surveys which comment upon the experimental and field studies are [27, 98, 206, 348, 372]. Schoemaker [315] provides a very readable brief survey of some of this literature. While the evidence is mixed, most studies indicate that the expected utility decision rule simply does not function well in a descriptive substantive sense.

In its simplest form, the expected utility of alternative a_i is computed from

$$E\{U(a_i)\} = \sum_{j=1}^{n} p[s_j(a_i)]\, U[s_j(a_i)] \tag{1}$$

where the $s_j(a_i)$, $j = 1, 2, \ldots, n$, are the states which may result from alternative a_i and the $p[s_j(a_i)]$ are the associated probabilities. In the expected utility formulation, the $p[s_j(a_i)] = p_j(a_i) = p_j$ are assumed to be objective probabilities and, of course, $\sum_{j=1}^{n} p_j = 1$. Generally these probabilities are not alternative invariant although notationally they are sometimes written as if they were independent of alternatives. The $U[s_j(a_i)]$ are the utilities, or values [296], of the decisionmaker for the various outcome states. Johnson and Huber [179] survey a number of procedures that can be used to elicit utility functions. Most of the text books cited earlier also contain discussion of utility assessment procedures.

Subjective Expected Utility. Often it occurs that objective probabilities are, for any of a variety of reasons, unavailable in a given situation. The subjective expected utility model is obtained when subjective probabilities $f(p_j)$ are substituted for the p_j in Eq. (1). The $f(p_j)$ are generally elicited such that $\sum_{j=1}^{n} f(p_j) = 1$ and so the subjective probabilities behave in a way consistent with the laws of probability. There are a number of discussions concerning probability elicitation [31,223,257,355] that present appropriate procedures to enable determination of subjective probabilities from individuals and groups. Conventional approaches to elicitation of utility in expected utility theory may confound strength of preference felt for alternative event outcomes and attitude toward risk. Also, the elicitation procedure can become cumbersome. Recent research has formally separated these factors [33] and shows much promise in enhancing understanding of attitude towards risk. In this approach, the utility concept is devoid of risk. It takes on a meaning more like that in conventional microeconomics where it measures strength of preference for certain outcomes only. This research [33] could provide additional linkages and understanding between the expected utility and subjective expected utility concepts by providing for incorporation of risk aversion effects in a relatively simple way. A related approach to incorporation of risk aversion is described by Howard and decision analysts at the Stanford Research Institute [164] who have been responsible for a number of major application studies in this area. There have been a number of related approaches [65,66,121] and the subjects of risk and uncertainty are of much contemporary interest [6, 136, 153, 304].

A number of studies have indicated that the relation between subjective and objective probabilities is nonlinear and situation dependent. It is usually indicated that people often underestimate high probabilities and overestimate low ones. More recent research has indicated that this appears true only for favorable outcomes. Just the opposite appears true when the outcome is unfavorable. This appears to be a form of wishful thinking for low probability events and "everything bad happens to me" for high probabilities. What we will call subjective utility theory attempts to incorporate situation dependent nonlinearities that may exist between subjective and objective probabilities.

Multiattribute outcomes. Often decision situations are sufficiently complex that it is difficult to evaluate, in a wholistic fashion, the utility of each outcome. Often it is possible to disaggregate the features, on which utility is based, into a number of components called attributes. An attribute tree is a hierarchical structure which, when quantified through elicitation of values of the outcomes on the lowest level attributes and relative weights of the attributes, can be used to determine the utility of event outcomes. The types of multiattribute utility models used have varied from very simple unit weight linear models to rather complex multiplicative models [106]. Dawes [71] documents the robust beauty of linear models of the form

$$U(s_i) = \sum_{j=1}^{m} h_j u_j(s_i), \quad \sum_{j=1}^{m} h_j = 1 \tag{2}$$

where there are assumed to be m attributes, h_j is the weight of the j^{th} attribute and $u_j(s_i)$ the value score on the j^{th} attribute of outcome s_i. In much of the work in this area, decisions under certainty are considered such that there is a one to one correspondence between alternative a_i and outcome s_i. Under decision-under-certainty conditions we can let $s_i = a_i$ in Eq. (2).

Multiattribute models have been very successfully used to predict the decision behavior, in field settings, or many professional groups. Hammond [140-142] and his colleagues have, as discussed in Section 3, developed an approach known as social judgment theory in which the "policy" of the decision maker, equivalent in this circumstance to the weights h_j, are identified from wholistic prioritization of decision outcomes through use of regression analysis techniques. Ward Edwards and his colleagues, in [186, 301] and elsewhere, elicit weights from decisionmakers for the model of Eq. (2) in a useful straightforward procedure called Simple Multiple Attribute Ranking Technique (SMART) that has seen a number of realistic applications. Results of the surveys of Armstrong [14, 15]; Fischer [111]; Slovic and Lichtenstein [345]; Slovic, Fischhoff and Lichtenstein [348]; Shanteau [324]; and others indicate that simple linear models [64] are very potent predictors of reliable judgment, especially under conditions of certainty, in that one can replicate the substantive judgment of decisionmakers. This is the case even though the simple linear model may not do a very good job of modeling the decision process. "Boot strapping" is the name given to the task of substituting a decision rule for the decisionmaker. The studies in the cited references show that the elimination of human judgment error

made possible by boot strapping enables it to be superior to unaided human judgment. One can even misspecify weights and ignore attribute dependencies and still find that weighted linear models do quite well [71].

The fact that the weighted linear rule may be so good is a rather mixed blessing. In circumstances in which there is no requirement for knowledge of the underlying decision process, the substantive predictive ability of the linear additive model may make it quite useful. Situations such as evaluating credit card applicants or applicants for admissions to colleges are repetitive judgment and decision situations which fit into this category. Use of a simple formal linear model may well, in situations such as these, lead to a more efficient as well as more effective and equitable selection process than one based on unaided human intuition [70, 71, Dawes in Shweder (332)]. In unstructured or semi-structured nonrepetitive decision situations, it is much less clear that a decision rule that is not guaranteed to be faithful to the underlying decision process will be nearly as valuable as one that is in terms of enabling decisionmakers to make better decisions. Fischhoff, Goitein, and Shipira [119] provide a number of perceptive comments concerning this, and the consequent need for a theory of errors to explicate the effects of poor decision situation structural models and parameters within the structure. A hoped for achievement is a sensitivity based analysis of deviations from optimality to determine, among other things, the role of experience in decisionmaking and those components and principles of decisionmaking which can be usefully and meaningfully learned from experience [47, 94-97, 115, 116].

Multiattribute utility models based on the expected utility theory of von Neumann and Morgenstern and considerably more complex than those of behavioral decision theory. Often there are efforts to determine existence of various attribute independence conditions such as to validate use of a linear model of the form of Eq. (2) or a multiplicative model of the form

$$1 + HU(s_i) = \prod_{j=1}^{m} [1 + h_j H u_j(s_i)], \quad \sum_{j=1}^{n} h_j = 1 \tag{3}$$

The foremost proponents of this approach are Keeney and Raiffa [196]. There are many contributions to this area and variations of the basic approach [23,29,75,93,127,231,277,278,300,301,302,358,398]. It is proposed exclusively as a normative approach and has been successfully used for a variety of applications including proposal evaluation [245, 310] siting power plants [197]; and budgeting and planning [52, 190].

Mean-variance - There are a number of models and associated decision rules based upon mean-variance (EV) models. Markowitz's portfolio theory, which is well summarized in Libby and Fishburn [214] and Baron [26], is based in part on the assumption of a quadratic utility function

$$U(s) = \alpha + \beta s + \gamma s^2 \tag{4}$$

where the same states are assumed invariant over all alternatives such that we have a quadratic programming problem in prioritizing alternatives where

$$E\{U(a_i)\} = \sum_{j=1}^{n} p_j(a_i)\, U(s_j)$$

$$= \alpha + \beta E\{a_i\} + \gamma E\{a_i^2\}$$

$$= \alpha + \beta \mu_i + \gamma(\sigma_i^2 + \mu_i^2)$$

Coombs [65, 66, 185] has also been concerned with portfolio theory and assumes an optimum risk level, in the form of a single peaked risk preference function, for every expected value level. Gambles of equal expected value are judged on the basis of lower variance in the Markowitz' portfolio theory, and on the basis of deviation from optimum risk level in Coombs' portfolio theory. Stochastic dominance concepts [124] are especially useful in dealing with problems in the mean-variance models of portfolio theory. Unfortunately, as has been shown by a number of authors [124], the results from using mean variance portfolio theory are not necessarily consistant with results obtained from expected utility theory. For example, if the outcomes of decision a_1 are \$10 with probability 0.5 and \$20 with probability 0.5 and the outcome of decision a_2 is \$10 with probability 1.0; then the EV rule (μ_{a1} = \$15, σ_{a2} = \$5) (μ_{a2} = \$10, $\sigma_{a2} = 0$) is indeterminate in that there is no pareto superior or dominance alternative in an EV sense. Yet any reasonable person would prefer alternative a_1 to alternative a_2.

Fishburn [123] has considered a variation of the mean-variance model which involves concepts based upon target level of return, or aspiration level, or reference level, to define the risk of an alternative. The "risk" of alternative a is determined from the probability of receiving a return not to exceed x, denoted F(x), by

$$R(a) = \int_{-\infty}^{t} (t-x)^{\alpha} \, dF(x) = \int_{-\infty}^{t} (t-x)^{\alpha} \, p(x) \, dx$$

where t is the target return, α is a nonnegative parameter that is used to indicate relative importance of deviations below target return. For $0 \leq \alpha < 1$ the decisionmakers primary concern is failure to achieve the target with little regard to the size of the deviation. For $\alpha > 1$ the decisionmaker is very concerned with sizeable deviations from target and relatively unconcerned with small deviations. In the former case, the decisionmaker is risk seeking for losses and has a utility function that is convex for losses. In the latter case, the decisionmaker is risk averse for losses and has a utility function that is concave for losses.

In this model, the mean return from an alternative and its risk are the two attributes determining preference. This model thus appears much similar to the standard EV model in that $a_1 \succ a_2$ iff $\mu(a_1) \geq \mu(a_2)$ and $R(a_1) \leq R(a_2)$ with at least one inequality being valid. In the example just considered, the mean values are as given previously and the risks are:

$$R(a_1) = \begin{cases} 0 , & t \leq 10 \\ .5(t-10)^\alpha , & 10 \leq t \leq 20 \\ .5(t-10)^\alpha + .5(t-20)^\alpha , & 20 \leq t \end{cases}$$

$$R(a_2) = \begin{cases} 0 , & t \leq 10 \\ (t-10)^\alpha , & 10 \leq t \end{cases}$$

Thus we see that the risk is the same, that is zero, if $t \leq 10$ and so we prefer a_1. The risk associated with a_1 is one half that associated with a_2 if the target return is between \$10 and \$20. The risk associated with a_1 is less than that associated

with a_2 if $t \geq 20$. And so, since $\mu(a_1) > \mu(a_2)$, we prefer a_1 regardless of the target return. Generally, as in this case, Fishburn's below-target model will resolve ambiguities associated with the standard mean variance model. The decisionmaker is free to specify α and t. Thus this represents a rather useful dominance type decision rule. Extensions of this rule to the case of multiattribute and multiple objective preferences would have considerable value.

Subjective utility theory. A number of researchers have proposed holistic decision rules based on the observation that people, in unaided situations, do not typically perceive (objective) probabilities such that the fundamental probability property $\sum_{j=1}^{n} p_j = 1$ is satisfied. There presently exists several decision situation models based upon a subjective utility theory in which probabilities do not sum to one. Among these are certainty equivalence theory, due to Handa [144]; subjectively weighted utility theory, due to Karmarkar [188, 189]; and prospect theory due to Tversky and Kahneman [184, 385]. There have been several additional studies involving prospect theory including those of Thaler [371], and Hershey and Schoemaker [152, 153]. Some of the foundations for these subjective utility theory efforts

can be found in the early work of Allais [3] who was among the first to note that the normative expected utility approach of von Neumann and Morgenstern, and the subjective expected utility modifications, did not necessarily describe actual descriptive choice behavior. We believe that these studies are especially relevant to information system design and so summarize relevant features from these effects here.

In certainty equivalence theory, five axioms are assumed. We will use the term prospect or prospect (s, P) to mean the opportunity to obtain outcome s with probability P. Simply stated, these are as follows:

1) Preferences are governed only by utilities and outcomes. One is indifferent between a nonsimple prospect and an actuarially identical simple prospect with a single event node.
2) Complete ordering of prospects is possible and transitivity of prospects exists.
3) Continuity exists such that if $(s_1, p_1) \succsim (s_2, p_2), \succsim (s_3, p_3)$ then there exists an α such that $(s_2, p_2) \sim (\alpha s_1, P_1) + (s_3 - \alpha s_3, P_3)$
4) Independence exists such that if $(s_i, p_i) \sim (x_i, 1)\ \forall i$, then $(\underset{\sim}{s}, \underset{\sim}{p}) \sim (\Sigma x_i, 1)$ where $\underset{\sim}{s}$ and $\underset{\sim}{p}$ represent vectors of outcomes and probabilities s_i and p_i.
5) Enhanced prospects are preferred if and only if a basic prospect is preferred. Thus $(\beta s_1, p_1) \succsim (\beta s_2, p_2)\ \forall \beta \geq 0$ iff $(s_1, p_1) \succsim (s_2, p_2)$

These axioms are sufficient to insure that the subjective utility function of alternative a_i, $CE(a_i) = CE[s(a_i), p(a_i)] = U(\underset{\sim}{s}^i, \underset{\sim}{p}^i)$, is linear in s_i and of the form

$$U(\underset{\sim}{s}^i, \underset{\sim}{p}^i) = \sum_{j=1}^{n} s_j^i\, w(p_j^i) = \underset{\sim}{w}^T(\underset{\sim}{p}^i)\, \underset{\sim}{s}^i \tag{5}$$

Axioms 1, 4 and 5 incorporate the major changes from the von Neumann Morgenstern axioms. It appears unduly restrictive to require that the utility function be linear in the outcome and this is reason enough to warrant the development of a more robust theory.

Fishburn [125], however, has shown that certainty equivalence theory must reduce to the expected value model, $U(\underset{\sim}{s}, \underset{\sim}{p}) = \underset{\sim}{p}^T \underset{\sim}{s}$, $\sum_{j=1}^{n} w(p_j) = 1$. This occurs because of the requirement that one must be indifferent between a nonsimple prospect and an actuarially equivalent simple prospect. To insure this for the two outcome case, for the general actuarially equivalent two outcome prospects of Fig. (4.2) requires that $w(p) + w(1-p) = 1$*. This certainty must be viewed as another limitation of this certainty equivalence theory and indicates the considerable care that must be exercized in modifying the basic utility theory axioms.

The subjective weighted utility model yields for the SWU of alternative a_i

$$SWU(a_i) = \sum_{j=1}^{n} w[P_j(a_i)]\, U[s_j(a_i)] \tag{6}$$

*For the n outcome case we would have $\sum_{j=1}^{n} w(p_j)=1$ and we see that the only general $w(p_j)$ that will insure this is $w(p_j) = p_j$.

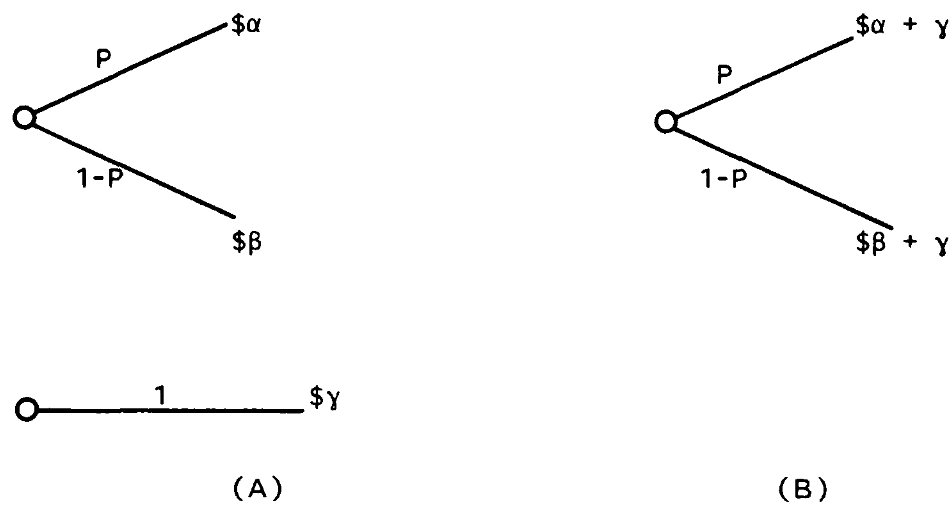


FIGURE 4.2 TWO ACTUARIALLY EQUIVALENT PROSPECTS

where the subjective weighted probabilities are

$$w[P_j(a)] = \frac{f\,[P_j(a)]}{\sum_{j=1}^{n} f[P_j(a)]} \tag{7}$$

Although a variety of probability weighting functions are possible, Karmarkar [188,189] proposes use of a log normal function

$$\ln\left(\frac{f}{1 - f}\right) = a \ln\left(\frac{P}{1 - P}\right) \tag{8}$$

or

$$f(P) = \frac{P^{\alpha}}{P^{\alpha} + (1 - P)^{\alpha}} \tag{9}$$

where $0 \leq \alpha \leq 1$. This transformation of probabilities is such that large probabilities are understated and small probabilities overstated. Karmarkar emphasizes that the probability weighting function does not represent a probability perception phenomenon but represents a bias in the way in which (objective) probabilities are descriptively incorporated into the evaluation, prioritization and choicemaking process. In this model, the final weighted probabilities do sum to one in accordance with the conventional subjective expected utility theory. However, the expression

for any normalized weight $w[P_j(a)]$ is actually a function of the value of all other probabilities as seen in Eq. (7). The effects of this confounding of influence remain to be investigated.

The considerably more sophisticated prospect theory of Tversky and Kahneman [184,385], contains a number of modiciations to expected utility theory. Prospect theory consists of an editing phase involving framing of contingencies, alternatives, and outcomes, followed by an evaluation phase. These modify subjective expected utility theory such as to enhance unaided descriptive realism of the theory:

1) In the editing phase, the decision situation is recast into a number of simpler situations in order to make the evaluation task simpler for the choicemaker. The tasks in editing are very much dependent on the contingency situation at hand and offer possibilities for coding, combining, segregating, cancelling, and detection of dominance.

2) Value functions are devoid of risk attitude, and are unique only up to positive ratio transformations.

3) Outcomes are expressed as positive or negative deviations from a reference or nominal outcome which is assigned a value of zero. Thus, value changes represent changes in asset position. Positive and negative values are treated differently with the typical value function being a S-shaped curve that is convex below the reference point and concave above it. Displeasure with loss is typically greater than pleasure associated with the same gain.

4) Probability weights, $w[P_j(a)]$, reflect an uncertain outcome contribution to the attractiveness of a prospect. As in SWU theory, high probabilities are underweighted and low ones overweighted. The following are among the properties of the probability weighting function:

a. true at extremes, $w(0) = 0$, $w(1) = 1$

b. subadditive at low P, $w(\alpha P) > \alpha w(P)$, $0 < \alpha$

c. overweighted for small p, $w(p) > p$, $p << 1$

d. underweighted for large P, $w(P) < P$, $P >> 0$

e. subcertain, $w(p) + w(1 - p) < 1$

f. subproportional $\frac{w(\alpha P)}{w(p)} \leq \frac{w(\alpha \beta P)}{w(\beta P)}$, $0 < \alpha, \beta, \leq 1$

5) The value of a prospect $(\underset{\sim}{s}, \underset{\sim}{P}) = (s_1, P_1) + (s_2, P_2)$ is given by

a) $V(\underset{\sim}{s}, \underset{\sim}{P}) = v(s_2) + w(P_1)\,[v(s_1) - v(s_2)]$ (10)

for strictly positive prospects in which $P_1 + P_2 = 1$ and $s_1 > s_2 > 0$, or strictly negative prospects in which $P_1 + P_2 = 1$, $s_1 < s_2 < 0$

b) $V(\underset{\sim}{s}, \underset{\sim}{P}) = w(P_1)\, v(s_1) + w(P_2)\, v(s_2)$ (11)

for regular prospects which are prospects that are neither strictly positive nor strictly negative in that either $P_1 + P_2 \neq 1$ and/or $v(s_1)$ and $v(s_2)$ are of opposite sign.

In no sense is prospect theory posed as a normative theory of how people should make decisions. The editing or framing of contin-

gencies, alternative acts, and outcomes is similar to the formulation step of the systems process. It is in this forming phase that the contingency task structure and decision situation model are, in effect, formed. For example, in a population of one million people where black lung disease might kill two thousand people, possible forms are:

Form 1 - alternative a_1 will save 500 people, whereas if alternative a_2 is adopted there is a 0.25 probability of saving two thousand people and a 0.75 probability of not saving anyone

Form 2 - alternative a_3 will result in death of 1500 people, whereas alternative a_4 will result in a 0.25 probability that no one will die and a 0.75 probability that 2000 people will die.

These two forms are really the same, yet many people will interpret them differently. The editing or forming phase of prospect theory allows different interpretations and thus makes provision for different evaluation of results in terms of alternative formulations of the same issue.

Prospect theory is especially able to cope with: _certainty effects_ in which people overweigh outcomes considered certain compared with those considered only highly probable; _reflection effects_ in which preferences are reversed when two positively valued outcomes are replaced by two negatively valued outcomes; and _isolation effects_ in which people disregard common outcome components shared by outcomes and focus only on components that distinguish alternatives. Kahneman and Tversky have established an axiomatic basis for prospect theory [184] for the two outcome case.

In a recent study involving prospect theory, Hershey and Schoemaker [152] question the generality of the reflection hypothesis of prospect theory which states that asymmetric preferences are found when comparing gain prospects with loss prospects. They introduce four types of reflectivity depending upon whether subjects choose positive prospect (s_1, P_1) or the non inferior prospect (s_2, P_2), and whether they choose negative prospect ($-s_1$, P_1) or ($-s_2$, P_2). Across-subject and within-subject reflectivity are examined in terms of whether subjects do or do not choose, and do or do not switch from safe to risky prospects. They conclude that predictions of prospect theory concerning reflectivity depend upon the size of probabilities. For P large enough to insure underweighting of probabilities, it appears that the reflectivity hypothesis is quite valid. For smaller values of P, reflectivity is neither predicted nor excluded from the results of Hershey and Schoemaker.

In another study, Hershey and Schoemaker [153] examine preferences for basic insurance-loss lotteries and show that risk taking, is prevalent in the domain of losses. They suggest a utility function which is concave for low losses and convex for larger ones. They indicate a context effect in which various insurance formulations lead to more risk averse behavior than for statistically equivalent gambling formulations. Their conclusion, that probabilities and outcomes may be of less guidance in influencing decision behavior as uncertainties concerning their magnitude increase, strengthens conjectures concerning the influence of con-

text and perceptions of decision situation structural models upon decision results.

Thaler [371] examines a number of the tenets of prospect theory with generally very-positive confirming results. Additional comments concerning the seminal prospect theory appear in a previous survey in these transactions [3C4] including the observation that a number of the results of prospect theory, which are seemingly at variance with expected utility theory, can be accomodated successfully using multiple attribute utility theory. Extentions of prospect theory to include multiple attribute preferences, large numbers of outcomes, sequential multistage decisionmaking, risk aversion coefficients, and subjective probability effects, would do much to enable this significant development to be of even greater usefulness in explaining complex positive, or descriptive, decision behavior. This might well be of much normative use as well.

Heuristic Decision Rules

A number of decision rules do not involve comparisons in a true holistic fashion. Rather, they involve comparisons of one alternative with another, generally within a restricted alternative set and attribute set. Within the heuristic class of decision rules, we may distinguish those which compare alternatives against some standard by means of conjunctive or disjunctive comparisons, those which compare alternatives across attributes, and those which make comparisons within attributes. All of these rules can result, when improperly applied, in intransitive choices [289]. We will consider several rules from each sub category. First we will discuss two noncompensatory rules [90] that are often used when there is an overabundance of data present.

Disjunctive - a disjunctive decision rule is one in which the decisionmaker identifies minimally acceptable value standards for each relevant attribute. Alternatives which pass the critical standard on one or more attributes are retained. Alternatives which fall below the critical standards on all attributes are eliminated. A single alternative is accepted when the critical standards are set such that all but one alternative fail to exceed any of the critical standards on any attributes. Unlike MAUT rules, where poor performance on one attribute can be made up by good performance on other attributes such that the rule is compensatory, a disjunctive decision rule is noncompensatory. A compensatory approximation to a disjunctive decision rule for attributes s_i is

$$U = \sum_{i=1}^{m} \frac{1}{\left(1 + \frac{s_i}{c_i}\right)^{n_i}} \qquad n_i >> 1 \qquad (12)$$

where m represents the number of attributes and c_i is the critical value on the i^{th} attribute. If U is greater than one, the alternative in question is retained.

Conjunctive - a conjunctive decision rule is one in which minimally acceptable value standards for each relevant attribute are identified. Alternatives are acceptable if they exceed all minimum standards. They are rejected if they fail to exceed any minimum standard. The critical values for disjunctive and conjunctive rules are generally different. A compensatory approximation to the noncompensatory conjunctive decision rule is

$$U = \prod_{i=1}^{m} \frac{1}{\left(1 + \frac{c_i}{s_i}\right)^{n_i}} , \qquad n_i >> 1 \qquad (13)$$

An alternative is retained if the corresponding utility U, is above a threshold which is set just slightly below 1. These approximations for the disjunctive and conjunctive rules become noncompensatory as n_i approaches infinity.

By iterating through the conjunctive acceptance and disjunctive rejection rule several times with adjustable critical values or aspiration levels, these rules become, in effect, forms of satisficing rules.

Dominance models and additive difference models are two examples of models which lead to decision rules involving comparison across some, but not necessarily all, attributes. No minimum standard of performance on attributes, that is to say minimum aspects, are identified.

Dominance - a dominance decision rule is one which chooses alternative a_1 over a_2 if a_1 is better than a_2 on at least one aspect and not worse than a_2 on any other aspect. An aspect is the score of a specific attention on a specific attribute. There are a number of applications of dominance theory, including stochastic dominance, to decisionmaking situations [33,54,75,124,358,398].

Additive difference - in an additive difference rule [382-385], a binary choice is made between alternatives a_1 and a_2. Differences are considered between values for a_1 and a_2 on each relevant attribute. Differences of the form $U_i(a_1) - U_i(a_2)$ are computed. Each of the differences is weighted in proportion to the importance of the differences between alternatives on the

various attributes. The resulting weight is $f_i[U_i(a_1) - U_i(a_2)]$. Alternative 1 is preferred to alternative 2 only if

$$\sum_{i=1}^{n} f_i[U_i(a_1) - U_i(a_2)] > 0$$

This is a compensatory rule and can be used to compare any number of alternatives merely by retaining the winner in each comparison [272]. Only if the functions f_i are linear will the additive difference rule necessarily lead to transitive choices.

A third important subcategorization involves comparison within attributes. There are a variety of lexicographic procedures [123] and the elimination by aspects rule [381, 382] which explicitly involve comparison of alternatives on one, or at most a few, attributes.

Lexicographic decision rule. This rule prescribes a choice of the alternative which is most attractive on the most important attribute. If two aspects on this attribute are equally attractive, the decision will be based upon the most attractive aspect on the attribute next in order of importance, etc.

Minimum difference lexicographic rule. This rule is much like the lexicographic rule, with the additional assumption that for each attribute there is a minimum acceptable difference, Δ_i, of alternative scores. Thus, only differences greater than Δ_i between the attractiveness values of two alternatives may determine a decision. If the difference on the most important attribute is less than Δ_i, then the attribute next in the lexicographic order is considered. The lexicographic semi-order rule is a special case of this decision rule where Δ_i is defined only for the most important attribute. For all other attributes $\Delta_i=0$. This procedure may easily be extended to cases where the Δ_i are defined

for the two most important aspects. This rule is often used in situations where information about attributes are missing as a result of imperfect discrimination among alternatives on a given attribute or of unreliability of available information. In general, this rule leads to intransitive choices when there are more than two alternatives. It may even lead to agenda dependent results for the case where there are only three alternatives. One should be especially careful to examine relations used for ordering alternatives to attempt to detect use of heuristics such as this, especially if concepts such as transitivity are used, perhaps inferentially, to determine partial orderings. This suggests the need for special care when attempting to use transitivity concepts to infer ordinal preferences. The resulting failure to seek disconfirming information may well create structural preference illusions.

Einhorn [96, 97] uses the term "outcome irrelevant learning structure" to describe processes which uses deficient heuristics, and which then reinforces poor choices through experiences involving feedback and lack of discomfirming evidence. These OILS may result either from unaided judgment processes; or from poorly conceived or possibly well conceived but improperly utilized, and therefore irrelevant, systemic methods or processes.

<u>The maximizing number of attributes in greater attractiveness rule</u>. This rule prescribes a choice of the alternative that has the greater number of favorable attributes. Specifically, the rule requires that the aspect of a decision alternative must be classified for each attribute as better. equal, or worse than the attractiveness

of the other alternative on that attribute. The preferred alternative will be that which has the greatest number of favorable classifications.

Elimination by Aspects [288, 381]. In this rule, attributes are assumed to have difference importance weights. An attribute is selected with which to compare alternatives with a probability that is proporational to its weight. Alternatives which do not have attribute scores above some aspiration or critical level are eliminated. A second attribute is selected with probability proportional to its weight and evaluation by elimination continues. The elimination by aspects model is thus seen to be a lexicographic rule in which decision forming attributes are picked according to a probabilistic mechanism.

Wholistic Decision Rules

It is not possible to provide anywhere near a complete listing or discussion of the many possible wholistic decision rules. Three of these wholistic judgment processes occur perhaps more frequently than others: standard operating procedures, intuitive affect, and reasoning by analogy.

Standard operating procedures. Standard operating procedures may result from the application of holistic or heuristic procedures, or other wholistic judgment approaches. A standard operating procedure is essentially what the name implies, a set of experience based guides to behavior which are typically used without resort to the underlying rationale which led to the procedure. Often standard

operating procedures are formulated by one person or group and then implemented by another person or group. Sometimes they involve habit or folk custom, such as "drink white wine with fish". Contemporary popular music contains a vast number of modern "standard operating procedure" proverbs, many of which are seemingly irrational [282].

Often user's guides and operating manuals are written in attempts to standardize operating procedures for performance. The greatest value of these procedures is as a checklist, reminder, or options, profile of attributes to look for, judgments to make or activities to select or perform. A fundamental often occurring difficulty is that an expert may be able to use a checklist or profile of options as a guide to performance based upon the ability of the expert to quickly recognize the features inherent in the situation. Lack of training and experience will often make it not possible for the novice to utilize this capacity for task need recognition. Klein and Weitzenfeld [202, 230] pose that: the lack of training and experience inherent in the novice, the associated lack of ability to recognize contextual relations and analogous situations, and the inability of guides to be able to teach this ability, are all fundamental impediments to the use of many standard operating procedure type guides to judgment and performance.

<u>Intuitive Affect</u>

A person who makes judgments based on intuitive affect typically takes in information by looking at the "whole" of a situation rather than by disaggregating the situation into its

component parts and acquiring data on the parts. Valuation is typically based on an attempt to determine whether alternatives are pleasant or unpleasant, likeable or unlikeable, good or bad for individuals. It stressed the uniqueness of personalistic value judgments. Zajonc [410] presents a very useful discussion of affect or feeling as postcognitive activity.

Reasoning by Analogy [130, 360]

Many philosophers of science claim that reasoning by analogy is the basis of hypothesis generation. It is fundamentally different than deductive inference or inductive inference based reasoning. In analysis inference we use analogies, prototypes, or other paradigms with which we are familiar to guide us in new tasks. These exemplars encourage recognition in a present situation in terms of experientially based knowledge.

Doubtlessly analogic reasoning, as well as reasoning by intuitive affect and standard operating procedures, are each heavily influenced by the contingency structure of the task at hand and the environment. These are the judgment processes used by many in reaching decisions. We will comment further in Sections 5 and 6 upon wholistic judgment and its role [81, 82, 98, 116-119, 202, 203] in choicemaking.

In this section we have examined a number of decision rules. We have discussed holistic, heuristic, and wholistic rules. The holistic models or rules are generally substantive and not necessarily process models. They may be prescriptive or descriptive in intent and use. The heuristic and wholistic models are more process oriented than the heuristic models. In unaided

situations people generally do not have the cognitive stamina to utilize the holistic rules, or may not sense a need for them even if they could utilize them. A variety of contemporary research [273-275] has presented the strongest of evidence that choice of decision rules is very task dependent and actual choices may vary appreciably across different interpretations of the same decision situations. Preference reversals have even been noted with translation of gambles and target return, reference point, or aspiration level effects. Phenomena such as these have recently been studied [274] and shown to be potentially explainable by a descriptive model of risky choice due to Fishburn [123] and by prospect theory.

We note that people use different decision rules and models at different phases of a decision process as a function of a number of influencing variables, such as education, experience, motivation, familiarity with the environment, and above all, stress. Etzioni [103, 104] has proposed a mixed scanning model of decisionmaking that forms the basis for some current research in information systems for planning and decision support [75, 76, 245, 398]. There are a number of contemporary efforts and approaches that support the design of systemic aids that will be more responsive to decisionmaker requirements. Especially important in this regard are the efforts of Einhorn, Kleinmuntz and Kleinmuntz [95], Hogarth and Makridakis [161], Huber [168], Jungerman [181], Kleinmutz and Kleinmutz [204], Lad [208], Libby [213], Montgomery and Svenson [256], Payne [271-275], Rouse [299], Svenson [364, 365], Thorngate [372], Toda [373-375], Tversky and Sattagh [384],

Tweney, et. al. [387], Vlek [392, 393], Wallsten [395, 396]. Efforts which concern the integration of descriptive and prescriptive components of decisionmaking [142, 307, 322, 323], efforts which concern determination of cognitive choice models in realistic settings [22, 88, 157, 158, 314, 325] efforts which involve formulation and structuring of decision situations [1, 247, 248, 255, 265, 286, 287, 300, 301, 302, 353, 397] and efforts which involve the cognitive effort involved in decision making [180, 328], may offer much promise as well.

5. Contingency Task Structure Models

The designer of information systems for planning and decision support must be concerned both with normative models of decision and choice processes and with descriptive models of how people perform, and can perform, in given situations. Thus, our discussions of information processing and decision or evaluation rule selection in the previous two sections take on particular meaning in that they comment on the wide variety of possible behaviors. We will be especially concerned, in this section, with describing cognitive processes as they are influenced by the contingency structural elements of task, environment; and the human problem solver's experience with these. There have been a limited number of efforts to describe these such as, those by Allais and Hagen [3]; Beach and Mitchell [32]; Borgida and Nisbett [42]; Broadbent [49]; Bunn [53]; Carrol [50]; Dreyfus and Dreyfus [82]; Einhorn [96,97]; Einhorn and Hogarth [98]; Harsanyi [147]; Hauser [149]; Howell and Fleishman [165]; Huber [168]; Janis and Mann [176,177]; Jungerman [182]; Klein [202,203]; Kleinmutz and Kleinmutz [204]; Kunruether and Schoemaker [207]; MacKinnon and Wearing [233]; Montgomery and Svenson [256]; Payne [272, 275]; Sage [308]; Simon [338,340,341,343]; Soelberg [353]; and Wallsten [395,396]. This is an area in which additional research could pay major dividends in ultimately increasing the effectiveness of information systems in coping with the contingency task structure variables in planning and decision support.

The contingency task structure model we first describe is related

to Piaget's theory of intellectual development [43, 126, 131, 205,262, 362]. After a description of this model [308] we indicate implications for information system design and the relationship of this model to models that have been proposed by others.

Insights into the nature of cognitive development and insights into a conceptual model of cognitive activity is contained in the works of Piaget, the founder of "genetic epistemology". According to Piaget, there are four stages of intellectual development:

1) sensory motor
2) preoperational
3) concrete operational
4) formal operational

The last two of these are of particular importance to our efforts here. In the writings of Piaget, intellectual development is seen as a function of four variables:

1) maturation
2) experience
3) education
4) self regulation - a process of mental struggle with discomforting information until identification of a satisfactory mental construction allows intellectual growth or learning.

In Piaget's model of intellectual development, concrete operational thinkers can deal logically with empirical data, manipulate symbols, and organize facts towards the solution of well structured and personally familiar

problems. Formal operational thinkers can cope in this fashion also. A major difference, however, is that those concrete thinkers who are not also capable of formal thought lack the capacity to reason hypothetically and to consider the effect of different variables or possibilities outside of personal experience. Concrete operational thinkers, for instance, will often have difficulty in responding "true" or "false" to the statement, "six is not equal to three plus four". As another example: "A card has a number on one side and a letter on the other; test the hypothesis that a card with a vowel on one side will have an even number on the other side". Concrete operational thinkers will have difficulty selecting cards for bottom side examination if the top sides of four cards are a, b, 2, 3. However, failure to pick the cards with "a" and 3 on top may not indicate inability as a formal operational thinker but, rather, failure to properly diagnose the task and determine the need for formal operational thought.

We wish to develop a model of higher order cognitive processing that describes the mature adult decisionmaker. Such a decisionmaker will typically be capable of both formal and concrete operational thought. As we will argue, selection of a formal or concrete cognitive process will depend upon the decisionmaker's diagnosis of need with respect to a particular task. That need will depend upon a decisionmaker's maturity, experience, and education with respect to a particular problem. Each of these influence cognitive strain or stress, a subject that will be discussed later in this section. Ordinarily, a decisionmaker

will prefer a concrete operational thought process and will make use of a formal operational thought process only when concrete operational thought is perceived inappropriate. In general, a concrete operational thought process involves less stress and may well involve repetitive and previously learned behavioral patterns. Familiarity and experience, with the issue at hand or with issues perceived to be similar or analogous, play a vital role in concrete operational thought. In novel situations, which are unstructured and where new learning is required, formal operational thought is typically more appropriate than concrete operational thought.

We see, in the foregoing discussion, the dominant role of the contingency task structure in guiding problem solving efforts. In concrete operational thought, people use concepts which:

1) are drawn directly from their personal experiences;
2) involve elementary classification and generalization concerning tangible and familiar objects;
3) involve direct cause and effect relationships, typically in simple two-variable situations;
4) can be taught or understood by analogy, algorithms, affect, standard operating policy, or recipe; and which
5) are "closed" in the sense of not demanding exploration of possibilities outside the known environment of the person and stated data.

In formal operational thought, people use concepts which may:

1) be imagined, hypothetical, based on alternative scenarios, and/or which may be contrary to fact;
2) be "open ended" in the sense of requiring speculation about unstated possibilities;
3) require deductive reasoning using unverified and perhaps flawed hypotheses;

4) require definition by means of other concepts or abstractions that may have little or no obvious correlation with contemporary reality; and which may
5) require the identification and structuring of intermediate concepts not initially specified.

Formal operational thought involves three principal stages:
1) reversal of realities and possibilities
2) hypothetico-deductive reasoning
3) operations on operations

as shown in Figure 5.1. These are accomplished through reflective observation, abstract conceptualization and the testing of the resulting concept implications in new situations. It is in this way that the divergence produced by discomforting new experiences allows the learning of new developments and concepts to be "stored" in memory as part of ones concrete operational experiences.

A number of the cognitive style investigations discussed in Section 2 have concluded that "abstract" decisionmakers are more information oriented and would typically process much information in complex decision environments. "Concrete" decisionmakers, on the other hand, could be expected to reach an information overloaded state at lower levels of environmental complexity; hence they would tend to process less information than would the abstract decisionmaker. Some models of cognitive style are based on the assumption that "concrete" decisionmakers need more information to arrive at a decision than do "abstract" decisionmakers, suggesting that "concrete" decisionmakers do not give existing information its full worth and more are prone to fits of skepticism than "abstract" decisionmakers. At first glance, cognitive style models such as the one suggested here appear to

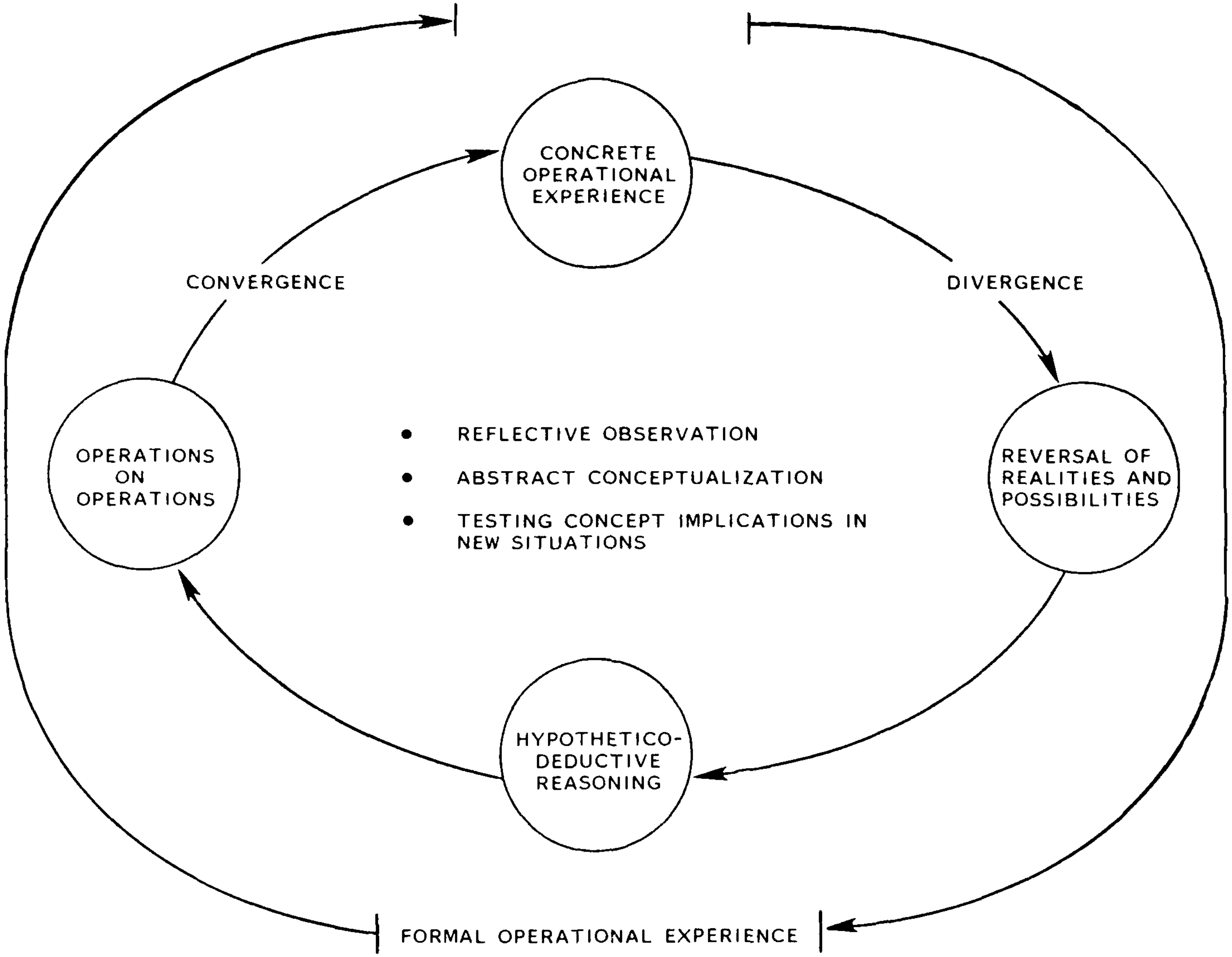


FIGURE 5.1 LEARNING THROUGH FORMAL OPERATIONAL EXPERIENCES

run in parallel to Piaget's concepts of concrete operational and formal operational thought. But there are very important and very significant differences. These are explicable through the contingency task structure and concept of task, environment, and decisionmaker; a concept that appears, with some notable exceptions, missing in much of the existing cognitive style research cited in Section 2.

The concrete operational thinker does not necessarily have limited abilities to process or integrate information; and the "formal" operational thinker is not necessarily capable of "abstract" thought in the specific contingency situation at hand. The formal thinker is neither necessarily able to process information which encompasses more complexity, nor better able to cope with uncertainty and disjointedness in the decision environment than is one who uses concrete operational thought in a given decision situation. Our contingency task structural model for the mature, perhaps expert, adult decisionmaker is one in which the decisionmaker may use formal or concrete operational thought based primarily on diagnosis of the contingency structure of the decision situation, and the stress that is perceived to be associated with the decision situation. This election of a formal or concrete operational mode of thought may be appropriate or inappropriate.

Systemic process design must be responsive to the observation that there are two fundamentally different thought or cognition processes. These are often associated with different halves of the brain [38,67,120,246-248,254,411]. One type of thought process is described by the adjectives: verbal, logical, sequenced, thinking, and analytical whereas the second is described as: nonverbal, intuitive, wholistic, feeling, and heuristic.

The verbal process is typically viewed as superior in engineering and natural science. But this viewpoint on the nature of thought appears wrong and should be discouraged as positively harmful. For, the two processes are complementary and compatible. They are not competitive and incompatible in any meaningful way. One thought process may be deficient, in fact, if it is not supported by the other. The nonverbal supports the verbal by suggesting ideas, alternatives, etc. The verbal supports the nonverbal by expressing, structuring, analyzing and validating the creative ideas that occur in the nonverbal process. An appropriate planning and decision support process must provide for verbal and nonverbal support. An appropriate planning and decision support process must be tolerant and supportive of a decisionmaker's cognitive (thought) processes. These will typically vary across individuals and within the same individual as a function of the environment, the individual's previous experience with the environment, and those associated factors which introduce varying amounts of stress. Thus, a contingency task structural view of individuals and organizations in decision situations is needed; as contrasted with a stereotypical view in which individuals are assumed to process fixed, static, and unchanging cognitive characteristics which are uninfluenced by environmental considerations.

Typically, we learn from experience and adopt various decision rules in the form of cognitive heuristics based upon this experience. The strength of belief that we have in the

usefulness of heuristics is often based on reinforcement through feedback. Einhorn [96,97] has described several supporting illustrations of this. As we have indicated in Section 4, the use of various types of lexicographic semiorders often lead to intransitive choices, which are often not recognized as intransitive. We often define issues by content rather than structure and convince ourselves to like what we get from a decision. As a consequence, we find it hard to separate decisions from outcomes in retrospective evaluations of our judgments. Much of this is probably due to changing our attitudes and our perceptions in a very selective way without being aware of the change, and to changing our forecasts, retrospectively, to correspond to events that have occurred without recognizing this change [117-119]. Thus we adopt a hindsight or "knew it all along" bias influenced by a variety of highly selective perceptions of reality.

We are most likely to have coherent value preferences and are able to develop and utilize appropriate evaluation heuristics in well-structured situations, with which we are familiar. Learning by trial and error and development of judgment based on either reasoning by analogy, standard operating procedures, or organizational rules, typically results from these "concrete operational" situations and experiences. Long standing use of these "rules" results in purely affective judgment and decision responses. In a familiar and simple world, a "concrete operational" world, these judgment guides and judgment heuristics might well be, and in fact often are, quite acceptable. In a changing and uncertain environment, an environment that is different from the one with which we are familiar, we may well err considerably by

using these concrete operational world appropriate judgment heuristics. If we do not have a developed set of coherent values relative to a changing environment, we may respond affectively with the first alternative option that comes to mind. We may well adopt post decision behavior such as to support and maintain a chosen response, and employ cognitive biases and cognitive heuristics to justify this potentially ill chosen response. This results in an affective response, appropriate for a "concrete operational" situation when an analytical response, appropriate for a "formal operational" situation, is needed. In the Janis and Mann [177] terminology, we adopt a coping pattern based on unconflicted adherence or change whereas vigilance is called for.

A serious problem in practice is that we get used to very simple heuristics that are appropriate for "concrete operational" situations in a familiar world, and we continue to use them in "formal operational" situations in an unfamiliar world in which they may be very inappropriate. A typical heuristic is incrementalism: "Go ahead and crowd one more beast into the commons". Such a heuristic may be appropriate in the familiar situation our forbearers encountered in a new unexplored continent. But the "social traps" produced by such judgmental heuristics in a now crowded environment may be inappropriate. There are numerous contemporary issues to support this assertion.

Styles or modes of information processing, which includes information acquisition and information analysis, are of much importance in the design of information systems for interpretation of the impacts of proposed policy. Information acquisition refers to the perceptual process by which the mind organizes the verbal and visual stimuli that it encounters. As indicated

in Section 2, McKenney and Keen [242] discuss two modes of information acquisition, a preceptive mode and a receptive mode. We utilize essentially these modes for our model of information acquisition and analysis:

a) In preceptive acquisition and analysis, individuals bring existing experiential concepts and precepts to bear to filter data. They focus on structural relations between items and look for deviations from their expectations. They use then formal precepts as cues for acquisition, analysis, and associated structuring of data.

b) In receptive acquisition and analysis, individuals focus on contextual detail rather than presumed structural relationships. They infer structure and impacts from direct and detailed examination of information, generally including potentially discomfirming information, rather than from fitting it to their precepts.

There is nothing inherently good or bad in either mode of information acquisition, analysis, and associated structuring. The same individual may use different modes as a function of contingency task structure. Most people will have preferences for one mode or the other in a particular situation, depending upon their diagnosis of the contingency task structure and perceived needs to accomplish effective information interpretation and associated decisionmaking. It is our hypothesis that cognitive biases often arise, or are initiated, by use of a situationally incorrect mode of information acquisition and structuring. To use preceptive acquisition when receptive acquisition is more appropriate would appear to invite one or more of the

many biases associated with selective perception. To use receptive acquisition when preceptive acquisition is appropriate would appear to introduce much stress associated with the low likelihood of being able to resolve an issue in the time available.

Information evaluation and interpretation refers to the decision rule portion of the problem solution. We advocate a model based on the use of the Piaget theory of concrete and formal operational thinking as a useful precept for information evaluation and interpretation. These thought process models may be summarized as follows:

a) In concrete operational thought, individuals approach problems either through intuitive affect, analogic reasoning, or through following a standard operating policy or organizational processes, or some related process.

b) In formal operational thought, individuals approach problems through structuring in terms of imbedding realities into possibility scenarios, hypothetico-deductive reasoning, and interpretation in terms of operations on operations.

Figure 5.2 presents our conceptualization of information acquisition, analysis and interpretation; or problem solving styles. This figure does not illustrate, however, the fundamentally dynamic nature of this process model. Figure 5.1 has presented some of the dynamic learning experiences which link the concrete operational and formal operational thought processes. Again we argue that no

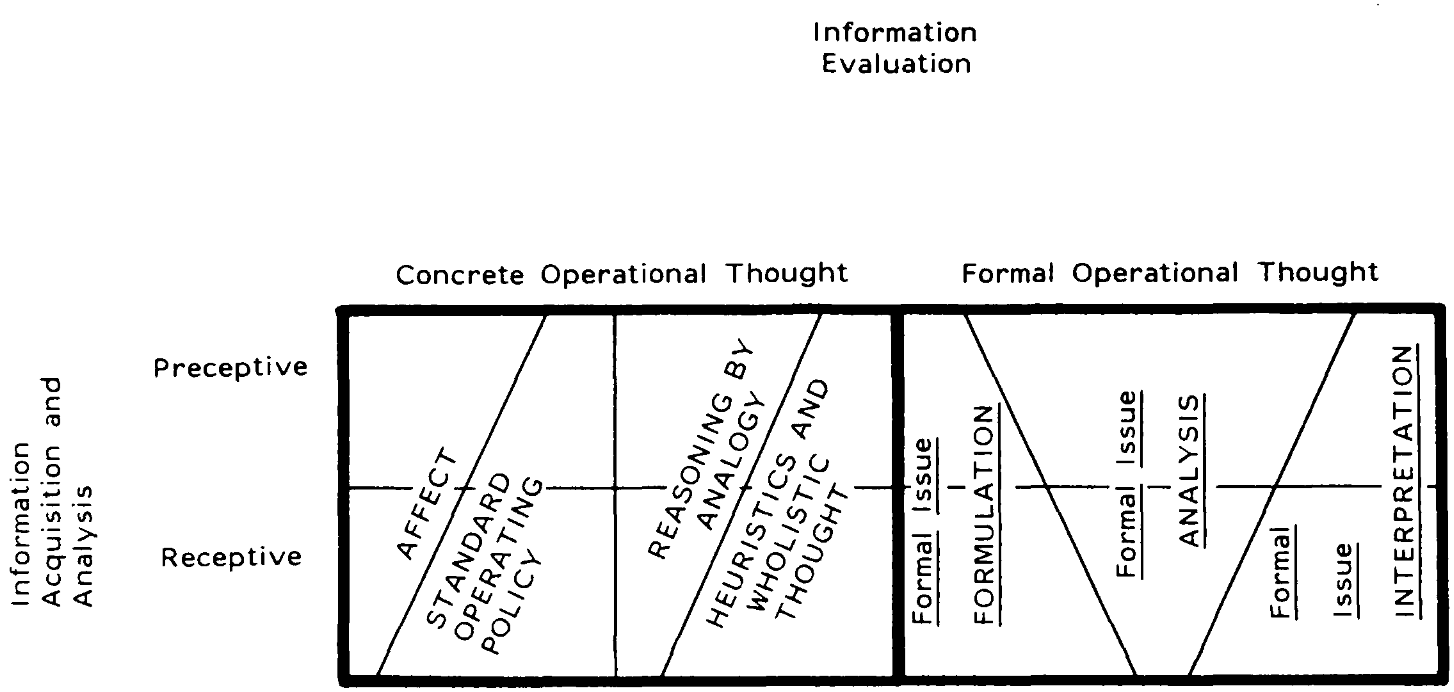


Figure 5.2 Conceptualization of Problem Solving Styles

style is inherently appropriate or inappropriate. Appropriateness of a particular style, as has been mentioned before, is very much task, environment, and experience dependent. That most decisionmakers function as concrete operational thinkers is doubtlessly correct. A principal task of a well designed information system is to assist in aiding the decision maker to detect the appropriate style for a given task, environment, and decisionmaker experience level. Another task is to enhance transfer of formal operational experiences to concrete operational experiences, such as through conceptualization and evolution of appropriate heuristics, wholistic thought, analogous reasoning guides, standard operating procedures, other forms of affective thought, and perhaps even precognitive responses. We posit that both types of information acquisition and analysis may occur with either concrete or formal thought; although the appropriate balance of receptive and preceptive acquisition and analysis will vary from situation to situation, as we have already indicated.

Our discussions have indicated the strong environmental dependence of the formulation, analysis, and interpretation steps necessary for problem resolution. These steps are necessary [illegible] in the resolution of any issue using systemic means, re[illegible] of the "style" adopted for problem solution. [illegible] izations, and technologies, are three dominant [illegible] engineering in general and for the des[illegible] and decision support in particular. [illegible]

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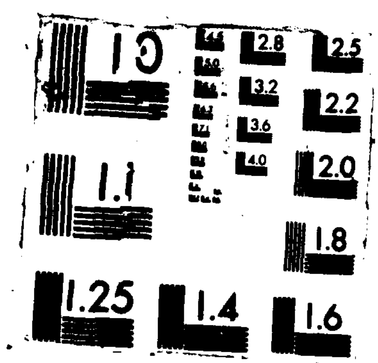
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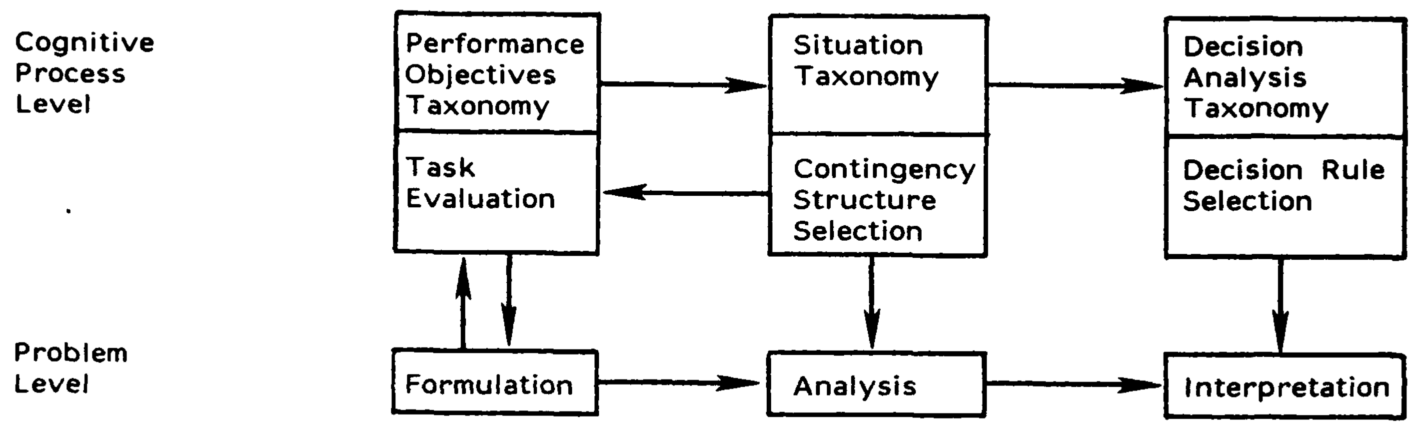

Figure 5.3 The Role of Systems Management in Determining Specific Problem Solving Approaches

environment with an organization and a technology that results in a management technology. Systems management is the term we use to denote the interaction of human judgment with methodological concerns [305-308]. Systems management denotes, therefore, concerns at the cognitive process level that involve the contingency task structure and its role in influencing the selection of performance objectives and decision rules for evaluation of options associated with issue resolution. There are many influences which act on the contingency task structure. Figure 5.3 indicates, conceptually, how the contingency task structure, and the environment which influences it, acts to specify and direct problem solving efforts.

It is our belief that the dynamic cognitive style models of Figures 5.1 and 5.2 can be used as guides to illustrate both those modes of information acquisition and information evaluation that should be used, and that will be used, on a given issue. We stress that the particular cognitive style most appropriate for a given issue will depend upon the decisionmakers familiarity with a given issue, the issue itself, and the environment into which the issue is imbedded. Thus a receptive or preceptive information acquisition style will be appropriate in a formal operational setting if the issue at hand is an unfamiliar and unstructured one. The appropriate balance between preceptive and receptive information acquisition will be dependent upon the type of issue and the experience or familiarity the decisionmaker has with possible information sources and their likely reliability. It will, of course, also be influenced by the "personal" style of

the decisionmaker and the type, if any, of interaction with the systems analyst as well as upon other characteristics of the decision situation. We accept the view that systems methodologies, especially as implemented through use of human judgment to form a systemic process, are highly value dependent. Different systems methodologies allow one to define issues in different ways and are responsive in differing amounts to value concerns, such as equity. Some methodologies explicitly encourage for example, detection of the use of deficient heuristics and encourage correction. The "transparency" and communicability of a decision process, for example, is very much a function of the methodologies used in process aiding for the formulation of issues, the analysis of alternatives, and associated interpretation efforts. This value dependence of systems methodologies is, therefore an important aspect of information system design and is related to performance objectives for the task at hand.

There have been a number of studies which focus upon the critical importance of task description and the decisionmaker's interaction with this task through the environment. Dawes [70,71] stresses the critical interaction among the mind and the task, and integrated models of the mind and the task requirements. He discusses the "even numbered-vowel" experiment described earlier in this section as does Anderson [7]. Anderson indicates that the failure, and a majority of educated adults do fail, to correctly resolve this task is due to difficulties in applying the modus tollens concept of conditional deductive reasoning, a concept which requires thinking about what is not the case. Anderson also discusses a slight variation of this task, which is

generally the same, and in which almost all subjects performed correctly. The task involved looking at four pictures of ordinary letter envelopes with the possibility of a stamp on them and picking the letters which should be turned over to test the hypothesis; if a letter is sealed, it has a 18¢ stamp on it. The critical difference between the two tasks is the fact that most people have experiences similar to the second task. It is relatively familiar compared to the first task,concerning which people do not have significant experience.

We should be rather cautious however in the apparently reasonable inference that we learn <u>correctly</u> from experience. A number of important studies by Brehmer [46, 47] have shown that by no means do people always improve their judgment and decisionmaking ability on the basis of increased experience. Biases, such as the tendency to use confirming evidence to the neglect of disconfirming evidence, are the key culprits. Brehmer [47] indicates how these biases can be understood in terms of available information. He concludes that truth is not manifest. It needs to be inferred in order to extract from experience information components that will truly lead to better judgments and decisions. The recent definitive discussion of judgment and choice processes by Einhorn and Hogarth [98] emphasizes the importance and the interdependence of attention, memory, cognitive representations, learning, conflict, and feedback. It provides much valuable perspective concerning the

importance of these topics for judgment and decisionmaking.

Carroll [56] is much concerned also with understanding decision behavior, especially through the process tracing techniques that have been emphasized by Payne [272-275]. Carroll proposes that the decisionmaker might better be portrayed as possessing a rich store of knowledge organized around a variety of evoked schemas, those complex units of organized knowledge which guide the acquisition and use of case information, rather than exclusively considering the decisionmaker as exhaustively following the prescriptions of normative models. Many of the chapters in the recently edited works of Estes [100]; Hamilton [137]; Howell [167]; Howell and Fleishman [165]; Schweder [332]; and Wallsten [396] discuss issues related to cognitive factors in judgment processes, including task descriptions for scripts, those stereotypical sequences of actions and event schemas, which often are of much use in explaining judgment.

Studies of information support for Air Force command and communication systems accomplished by Klein [202, 203] express a number of concerns regarding artificial intelligence and information processing approaches for decision aiding. These reservations concern potential inabilities of humans to disaggregate situations into components and to analyze these discrete components. He indicates that the proficient performance of experts may well be based more on reasoning by analogy than by representations in terms of step by step descriptions capable of (discrete) digital computer processing. Further, expert proficient performers may not follow explicit conscious rules.

Requiring them to do so may reduce performance quality, and they will be unable to accurately describe the rules that they do follow. Klein views expertise as arising from perceptual abilities including: recognitional capacity in terms of analogous situations, sensitivity to environmental context in the sense of appreciation of the significance of subtle variations, and sensitivity to intentional context by viewing the relevance and importance of task components as a whole by anticipating what has to occur to achieve a goal rather than just what will occur at the next time instant or step. He presents a comparison guided model of proficient decisionmaking. In this model [203]:

1. a current decision situation is perceived in terms of objectives;
2. the decisionmakers experience allows recognition of a comparison situation ;
3. similarities and differences between the comparison situation and the current situation are noted;
4. this application suggests options, including evaluation of options and selection of a preferred option based on what worked in the comparison option; and
5. the way the objectives and the decision is perceived, possible further adjustments of options,generation of new options, and combination of options, follow from this.

Klein strongly encourages development of decision aids to support the recognitional capacity of the expert; aids that will assist

the expert in recognizing new situations in terms of analogous comparison cases and in using these to define options or alternatives. The adjuvant would also keep track of options, assist in generation of new ones, and perform computations to assess the impacts of various options. It certainly appears that this is a needed and necessary role for information systems adjuvants for planning and decision support. But it must be remembered that not all users of such a system will be proficient and expert in all of the tasks they are to perform. We suggest the need also for provisions for formal operational thought type processes for those contingency task situations that have not been sufficiently cognized such that appropriate use of concrete operational thought necessarily leads to efficient and effective performance.

Dreyfus and Dreyfus [82] also argue that experienced and expert human decisionmakers solve new problems primarily by seeing similarities to previously experienced situations in them. They argue strongly that, since similarity based processes actually used by experienced and expert humans lead to better performance than formal approaches practiced by beginners, decisionmaking based on proven expertise should not be replaced by formal models. They pose a model which contains five developmental stages through which a person passes in acquiring a skill such as to become a proficient expert. Their basic tenet is that people demand less and less on abstract principles and more and more on concrete experience as they become proficient. Their five stages, and suggested instruction at each stage, are:

1. Novice - Decompose the task environment into context free nonsituational features which the beginner can recognize without experience. Give the beginner rules for determining action and provide monitoring and feedback to improve rule following.
2. Competence - Encourage aspect recognition not by calling attention to recurrent sets of features, but rather by singling out perspicuous examples. Encourage recognition of dangerous aspects and knowledge of guidelines to correct these conditions. Equal importance weights are typically associated with aspects at this stage.
3. Proficiency - This comes with increased practice that exposes one to a variety of whole situations. Aspects appear more or less important depending upon relevance to goal achievement. Contextual identification is now possible and memorized principles, called maxims, are used to determine action.
4. Expertise - The repertoire of experienced situations is now vast, such that the occurrence of a specific situation triggers an intuitively appropriate action.

5. Mastery -The expert is absorbed and no longer needs to devote constant attention to performance. There is no need for self monitoring of performance and energy is devoted only to identifying the appropriate perspectives and appropriate alternative actions.

Dreyfus and Dreyfus associate the development of these five skill categories with successive transformation of four mental functions. Figure 5.4[82] indicates how these transformations occur with increased stages of proficiency. While developed primarily for training, this model contains much of importance with respect to information system design to support planning and decisionmaking as well.

A key issue in this table would appear to be the development of concrete situational experience which first occurs when a person is able to recognize aspects. There seems to exist some complimentarity between our model of the cognitive judgment and decision process and that of Dreyfus and Dreyfus. The concrete operational thought of experienced decisionmakers would appear to be much the same as the thought of the expert and the master. Of course in all of these models ,"expert" is a relative term, with the environment and the contingency task structure of a specific situation needed to determine whether a decisionmaker is familiar and experienced with it. Some differences in the models are doubtlessly present as well. Some of these depend upon precisely what is meant by "processing information". Our definition is rather broad and certainly not restricted to quantitative processing. Generally information processing, in our view,

<table>
<tr><th colspan="2"></th><th colspan="4">MENTAL FUNCTION</th></tr>
<tr><th colspan="2"></th><th>RECOLLECTION OF SIMILAR FEATURES</th><th>RECOGNITION OF ASPECTS</th><th>DECISION PARADIGM</th><th>AWARENESS OF TASK</th></tr>
<tr><td rowspan="5">SKILL LEVEL</td><td>NOVICE</td><td>NON SITUATIONAL</td><td rowspan="2">DECOMPOSED</td><td rowspan="3">ANALYTICAL</td><td rowspan="4">MONITORING</td></tr>
<tr><td>COMPETENT</td><td rowspan="4">SITUATIONAL</td></tr>
<tr><td>PROFICIENT</td><td rowspan="3">WHOLISTIC</td></tr>
<tr><td>EXPERT</td><td rowspan="2">INTUITIVE</td></tr>
<tr><td>MASTER</td><td>ABSORBED</td></tr>
</table>

Figure 5.4 Dreyfus' Judgment and Decision Process Model

includes the formulation or acquisition, analysis, and interpretation of data of value for decisionmaking. This can be accomplished holistically, heuristically, or wholistically.

Very important concerns exist, in our view, with respect to possible cognitive bias and value incoherencies in the concrete operational decisionmaking of experts, or masters. Questions related to the effects of changing environments upon the judgment and decision quality of masters and novices alike are very important in all of these models. For intuitive experience may not be a good guide for judgments and decisions in uncertain, unfamiliar, and/or rapidly changing environments. But quantitative or qualitative analysis based efforts may well not be very good either due to changed decision situation and contingency task structural models. In our view it is possible to become a "master"; but unfortunately possible to become a master of the art of self deception as well as of a specific task. The external behavior of the two "masters" may well be the same; situational, wholistic, intuitive, and absorbed. What was an appropriate style for one "master" may well be inappropriate for another.

Behavior in familiar but uncertain environments is of much interest. Studies of failure, situations in which experts and masters fail or misdiagnose their degree of expertise or mastery, could yield exceptionally useful results and would also serve to incorporate and integrate much of the experimental work involving biases, poor heuristics, and value coherences into more real

decision situation. We hypothesize that the dynamic models of decision styles presented in this section will be useful vehicles to these ends.

Judgment and decisionmaking efforts are often characterized by intense emotion, stress, and conflict; especially when there are significant consequences likely to follow from decisions. As the decisionmaker becomes aware of various risks and uncertainties that may be associated with a course of action,this stress becomes all the more acute. Janis and Mann [176, 177] have developed a conflict model of decisionmaking. Conflict here refers to "simultaneous and opposing tendencies within the individual to accept and reject a given course of action". Symptoms of conflicts may be hesitation, feelings of uncertainty, vacillation, and acute emotional stress; with an unpleasant feeling of distress being, typically, the most prevalent of all characteristics associated with decisionmaking [49]. The major elements associated with the conflict model are: the concept of vigilant information processing, the distinction between hot and cold cognitions, and several coping patterns associated with judgments.

Cold cognitions are those made in a calm detached environmental state. The changes in utility possible due to different decisions are small and easy to determine. Hot cognitions are those associated with vital issues and concerns , and are associated with a high level of stress. Whether a cognition is, or

should be, hot or cold is dependent upon the task at hand and the experiential familiarity and expertness of the decisionmaker with respect to the task. The symptoms of stress include feelings of apprehensiveness, a desire to escape from the distressing choice dilemma, and self-blame for having allowed oneself to get into a predicament where one is forced to choose between unsatisfactory alternatives. Janis and Mann [177] state that "psychological stress" is used as a generic term to designate unpleasant emotional states evoked by threatening environmental events or stimuli. They define a "stressful" event as "any change in the environment that typically induces a high degree of unpleasant emotion, such as anxiety, guilt or shame, and which affects normal patterns of information processing." Janis and Mann describe five functional relationships between psychological stress and decision conflict:

1. The degree of stress generated by decision conflict is a function of those objectives which the decisionmaker expects to remain unsatisfied after implementing a decision.
2. Often a person encounters new threats or opportunities that motivate consideration of a new course of action. The degree of decision stress is a function of the degree of commitment to adhere to the present course of action.
3. When decision conflict is severe because all identified alternative pose serious risks, failure to identify

a better decision than the least objectionable one will lead to defensive avoidance.

4. In severe decision conflict, when the decisionmaker anticipates having insufficient time to identify an adequate alternative that will avoid serious losses, the level of stress remains extremely high. The likelihood that the dominant pattern of response will be hypervigilance, or panic, increases.
5. A moderate degree of stress, which results when there is sufficient time to identify acceptable alternatives in response to a challenging situation, induces a vigilant effort to carefully scrutinize all identified alternative courses of action, and to select a good decision.

Based upon these five functional relation propositions, Janis and Mann present five coping patterns which a decisionmaker would use as a function of the level of stress: unconflicted adherence or inertia, unconflicted change to a new course of action, defensive avoidance, hypervigilance or panic, and vigilance. These five coping patterns, in conjunction with the five functional relation propositions of psychological stress, were used by Janis and Mann to devise their conflict model of decisionmaking. This model postulates that each pattern of decision stress for coping is associated with a characteristic mode of information processing. It is this mode of information processing which governs the type and amount of information the decisionmaker will prefer. Figure 5.5 presents an interpretation of this conflict model of decisionmaking

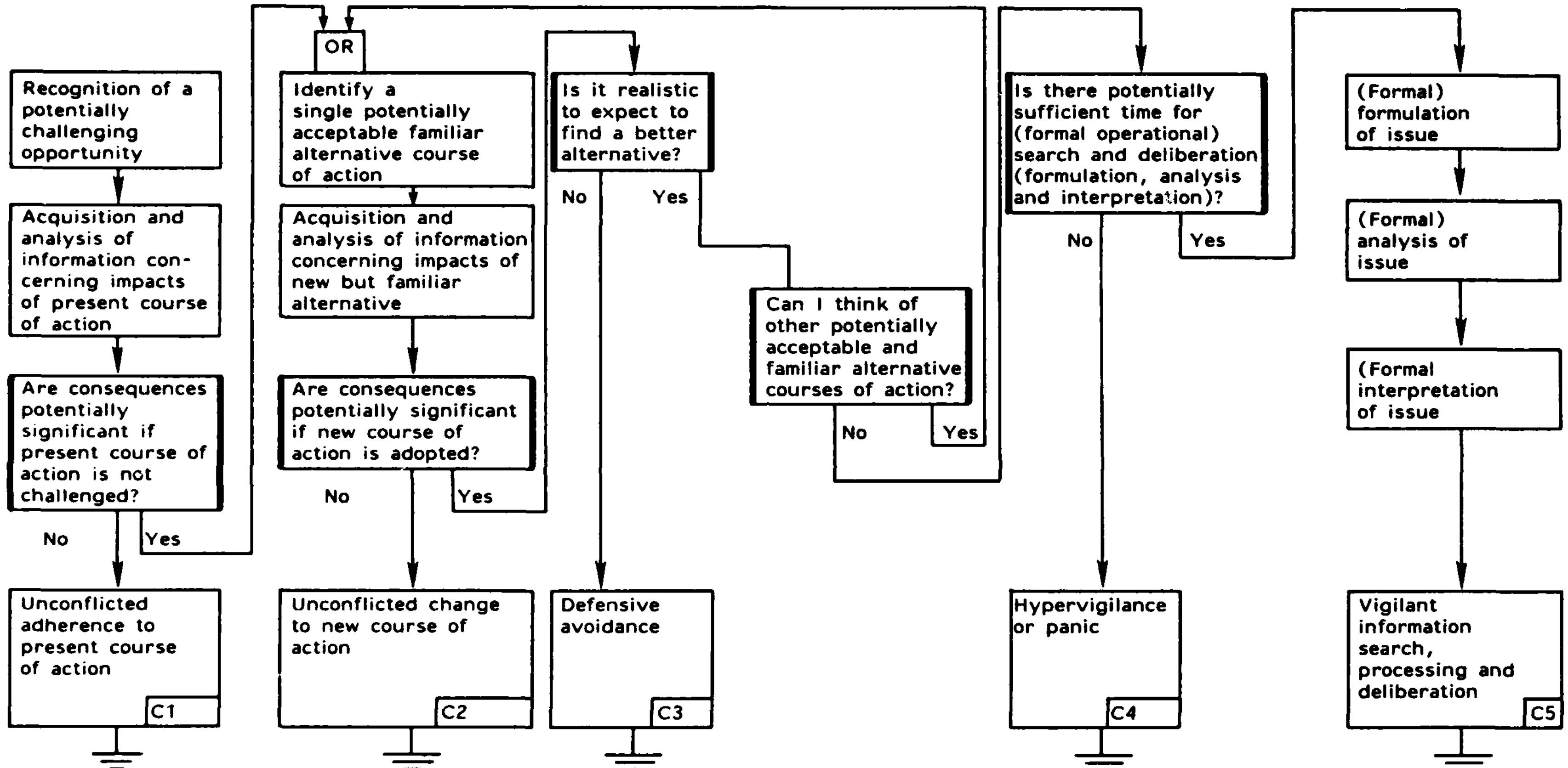

Figure 5.5 Interpretation of the Janis and Mann [177] Conflict Model of Decision Making

in terms of the systems engineering contingency models discussed in this section. This model points to a number of markedly different tendencies which become dominant under particular conditions of stress. These include open-mindedness, indifference, active evasion of discomfirming information, failure to assimilate new information, and all of the other cognitive information processing biases identified in Section 3. Table 5.1 summarizes information processing preferences and decision styles generated by this conflict model. The table depicts the striking complexity entailed by the vigilant information processing pattern in comparison to the other coping patterns. The vigilance pattern is characterized by seven key steps which require somewhat prolonged deliberation. The other four coping patterns require that only a few key steps be addressed. Selection of a coping pattern may be made properly or unwisely, just as selection of a decision style may be proper or improper. The seven steps of vigilant information processing appear quite equivalent to the steps of systems engineering.

Janis and Mann [177] combine the hypotheses they present concerning: the 4 stages of the decisionmaking (which we discuss in Section 1), the five functional relation propositions of psychological stress, and the five stress coping patterns. Also, they present a decision balance sheet, an adaptation of the moral algebra of Benjamin Franklin [177], on which to construct a profile of the identified options together with various cost

and benefit attributes of possible decision outcomes. They have shown that decision regret reduction and increased adherence to the adopted decision results from use of this balance sheet. Strategies for challenging outworn decisions and improving decisions quality are also developed in this seminal work.

It would be of considerable interest to indicate the typical interactions between this model of Janis and Mann, which would be an expanded version of Figure 1.1, and the other three contingency task structure models of decision style that we have discussed in this section. We believe each of these models to be appropriate and to portray different relevant features of task evaluation, information processing preference, and decision rule selection, in terms of contingency elements associated with the environment and the decision-maker's prior experiences.

Table 5.1 Interpretation of the Janis and Mann [177] Coping Patterns

Janis and Mann Coping Pattern	Likely information processing characteristics	Level of interest and importance attached to information & decision task	Stress level	Information evaluation style	Potential coping errors	Characteristics of possible errors	Characteristics of proper selection of coping pattern
Unconflicted adherence or unconflicted change	Indifference to information acquisition and analysis	Low	Low, calm demeanor	Concrete operational	Lack of interest in information processing has caused a generally unstructured and unfamiliar issue to be diagnosed as a familiar well structured, or an inconsequential, one.	An unconcerned tranquil journey to disaster	efficient and effective use of past experience to select an appropriate decision
Defensive avoidance	May vary from indifference to information, to highly selective processing of information to avoiding disconfirming information, thereby encouraging "wishful thinking".	Low to medium	Highly variable from low to high	Generally flawed and concrete operational. Inattention, delay, and refusal to evaluate and act.	Decisions are postponed, procrastinated, or avoided by shifting responsibility to others and ignoring essentially all information.	No decision is, in reality, a decision. One of the possible consequences of no decision will occur.	This is never a proper coping pattern; only "blind luck" will result in a good outcome.
					A form of wishful thinking is used to to evolve a decision. Highly selective perception is used to bolster the decision.	Often value labilities and inchoateness will result in accepting an hypothesis that the decisionmaker believes is deserving to be true as a self fulfilling prophecy.	
Hypervigilance	Very indiscriminate and erratic search	Very high	Very high	Flawed and formal operational	Failure in acquisition and analysis of information resulting from information overload due to panic.	Highly variable from snap judgments and acceptance of overly simplified and flawed decision rules to freezing such that valuable time, in which a good decision could be made, is lost.	This is never a proper coping pattern; only "blind luck" will result in a good outcome.
Vigilance	Openminded discriminating information acquisition and analysis. Typically this involves: a) thorough widescope canvas of potential alternatives b) identification of all relevant objectives c) thorough impact analysis d) intensive search for new information e) proper cognizing of disconfirming as well as confirming information f) sensitivity analysis to parameter changes g) detailed implementation provisions and contingency planning	High	Moderate	Formal operational	The issue is inconsequential or well within the experiential background of the decisionmaker.	Wasted time and possibly an inferior decision to one that could have been obtained from affect or or analogous reasoning or other concrete operational thought.	openminded discriminating search and deliberation involving an unstructured selection to select an appropriate decision.

6. Decision Making Frameworks and Organizational Settings

We have already discussed such topics as decision making rules, cognitive styles, information processing and contingency task structural models. Each of these represents a necessary component in the description of components of the decision making process. While these components are all necessary for understanding of the decision process, they are not sufficient. In particular, the nature of the decision making process is very much influenced by the topics to be discussed in this section: various types of reasoning; the degree of approximation to various conceptual models of decision making; the degree of centralization of the decision process; and the effects of these factors upon information acquisition. All of these factors are typically related and all are part of the contingency task structure. The central factor which is the basis for the determination of the way in which a decision maker adapts to various coping patterns and associated decision processes.

Characterizations of Rationality

Diesing [77] is among several writers, such as Steinbruner [359], who have defined several forms or types of rationality. Diesing defines five forms of rationality:

1. Technical rationality - This results from efficient achievement of a single goal. A technically rational organization

is one in which all of the activities of the organization are efficiently organized to achieve the goal of the organization. Technological progress requires an increase in the efficiency of the productive process and the existence of social conditions that make this increased efficiency possible. Diesing notes that a technological innovation that deals only with more efficient means to a single end will often have rather limited influence if the impacts of the technology and resulting attributes are morally and psychologically isolated from one another.

2. Economic rationality - This results from maximum achievement of a plurality of goals. There are four characteristics needed for existence of an economy. Two of these relate to allocation: plurality of alternative ends, common means to the ends, and scarcity of resources; and availability of a value system and associated measurements. Two characteristics relate to exchange: plurality of economic units; and a different prioritization of values among these units. Diesing claims that maximum goal achievement, or economic rationality, is possible if:

(a) the ends (goals) of the economic units are comparable and measurable on a single scale;

(b) there are no limits on the assignability and use of the means;

(c) economic units are integrated enough to engage in rational allocation and exchange; and

(d) information about the supply demand relationships for the various units is available and known to all.

Consequently economizing includes both evaluation and selection of various ends and means. Clearly, it is desirable that conditions (a) - (d) hold; but there exists many approaches to maximization under constraints that may be used to yield optimum resource allocation under constraints. Economic progress is equivalent to an increase in productivity per labor hour and, consequently, increased productivity can only result from economic and technical change. Economic progress will typically spread rapidly throughout a culture because it allows more and more ends to become both alternatives to each other, and means to other ends as well. Generally, the rational actor model we have discussed before is equivalent to Diesing's model of economic rationality.

3. Social rationality - A social system is an organization of cultural roles such as expectations, obligations, and ideals. A social system is said to be integrated when the various associated activities fit well, support, confirm, enrich and reinforce one another. Social integration is more than mechanical efficiency and consistency due to the mutual support, enrichment, confirmation, and reinforcement requirement. This integration makes action possible by:

(a) channeling emotional energy and preventing it from being diffused and lost;

(b) eliminating conflict which could block action;

(c) providing those supporting factors which strengthen action and which allow action to be carried through to completion; and

(d) making actions more meaningful by allowing them to be related to past and future actions.

An integrated social system is a rational social system that enhances the meaningful and successful completion of actions. Successfully completed actions are not necessarily either efficient or effective as integration promotes survivability of the system and not necessarily the people within it. In extreme cases of inefficiency or ineffectiveness, people may leave the system and establish another one. Five characteristics of a rational social organization, as described by Diesing, are:

(a) internally consistent roles that can be carried out by the society without great strain;

(b) harmonious roles that fit together without conflict among roles;

(c) smoothly evolving roles such that there exists continuity and stability with no sharp impulsive changes in roles over time; and

(d) roles compatible with the nonsocial (i.e., geographic, technoeconomic, temporal and physiological) environment.

As it develops and becomes more integrated, a social system develops a value system that reinforces, through feedback, the

structure of, and roles within, the social system. Well-integrated, socially-rational systems typically resist change and avoid risk in our interpretation of Diesing. One might argue, of course, that a well integrated social system should be adaptive to change and that failure to do so will subject it to a greater long term risk than if it were organically adaptive to change. This is, perhaps, the difference between a descriptive view and a normative view of a well integrated social system.

4. Legal rationality - A legally rational system is a system of rules which are complex, consistent, precise, and detailed enough to be capable of unambiguous application. Some of these rules may apply impartially to all people, while others may apply differently to different classes of people. A"legally rational" system is rational because, and if, it is effective in preventing disputs. It does this by providing a framework which defines and supports performance of economic and social rules. This framework also provides a procedure for settlement of those disputes which occur.

5. Political rationality - This is the rationality of decisionmaking structures. A decisionmaking structure is composed of a set of discussion relationships, and a set of beliefs and values that are imbedded into a set of recognized roles. These roles have been assigned to individuals such as to enable actions within the context of previous actions and commitments. Politically rational decision structures are based upon three guiding imperatives,according to Diesing:

(a) maintenance of independence of the group despite all pressures for dependence ;

(b) actions to structure the political group such that pressures are balanced and moderate; and

(c) preparation for future pressures which act to increase the stability and political rationality of the decision structure by providing unification and broadening of participation.

These forms of rationality are certainly related. Technical rationality is necessary for, and a part of, economic rationality. The primary characteristic which follows from rational economic behavior is a detachment or neutrality of intrinsically valueless commodities. These are useful only as means to ends such that scalar optimization may be used to select the commodity bundle of alternate means. Particularism and loyalty are the primary characteristics of social rationality such that obligations evolve from particular social relations with individuals and groups; rather than general, universalist detached relations which are applicable to all. Ascription, in which actions towards people evolve from particular relations rather than as a response to achievement, is another characteristic of social rationality. Thus, we see that the characteristics of economic rationality <u>may</u> contrast sharply with those of social rationality. But this, we believe, is not necessarily the case. For, as Diesing indicates, neither form of rationality can exist without some form of the other. Economic rationality

theories are based on the assumption that social integration is a reality; such that there exist communication and valuation capabilities, and no goal conflicts or factionalism. In a similar way, social rationality assumes that societies' economic resource allocation problems are solved.

Social and political rationality are related in the sense that both are primarily concerned with internal structural concerns involving process and procedure; that is, the structure of interpersonal relations, or the accumulation of power, or the direction of pressure. Economic and legal rationality are primarily concerned with the substantive behavior as contrasted with procedural and internal structural concerns. We have argued strongly in previous sections that substantive and procedural rationality [206,336] are each necessary considerations in information system design.

Decision Frameworks

We have presented a detailed synopsis of the perceptive work of Diesing [77] concerned with five different forms of rationality. Additional forms of rationality [50], perhaps based upon the ten interacting societal sectors noted in [304,307], could doubtlessly be developed. It would be of interest to determine the extent to which these additional forms of rationality would be subsets of, and independent of, the five forms of Diesing.

The organizational science literature contains much discussion relative to the development of conceptual models for decisionmaking based upon various rationality conceptualizations. Among these are: the (economic) rational actor model; the satisficing or bounded

rationality model; the bureaucratic politics, incremental, or "muddling through" model; the organizational processes model, and the garbage can model. These are related to the five types of rationality described by Diesing in relatively obvious ways that follow directly from a description of these decision frameworks.

1. The Rational Actor Model. The decisionmaker becomes aware of a problem, studies it, carefully weighs alternative means to a solution and makes a choice or decision based on an objective set of values. This is comparable to technical and economic rationality as described by Diesing. At first glance, the rational actor model appears to contain much of value and to be especially well matched to the detached neutrality, calculative orientation, and avoidance of favoritism associated with the achievement oriented entrepreneurial Western society. In rational planning or decisionmaking:

a) The decisionmaker is confronted with an issue that can be meaningfully isolated from other issues.

b) Objectives are identified, structured and weighted according to their importance in achieving need satisfaction on various aspects

c) Possible activities to resolve needs are identified.

d) The impacts of action alternatives are determined.

e) The utility of each alternative is evaluated in terms of its impacts upon needs.

f) The utilities of all alternatives are compared and the policy with the highest utility is selected for action implementation.

These are essentially equivalent to the vigilant information processing steps of Janis and Mann [177].

Unfortunately, there are several substantive requirements for successful complete rational decisionmaking that will not generally be met in practice. These include:

a) Comprehensive identification of <u>all</u> needs, constraints, and alterables relevant to planning and decisionmaking is, of course, not possible;

b) Determination and clarification of <u>all</u> relevant objectives is, of course, not possible;

c) Determination and minimization of costs and maximization of effectiveness will not necessarily lead to the "best" results because of of a) and b);

d) Detached neutrality and a calculative orientation rather than arbitrariness, conflict, and coercion are not always possible;

e) A unified process that will cope with interdependent decisions will often be very complex;

f) Sufficient time to use the method will often not be available;

g) Sufficient information to enable use of the method will often be difficult and expensive to obtain; and

h) Sufficient cognitive capacity to use the method will often not exist.

It has long been recognized by systems engineers and management scientists that the attempt to use a normatively optimum process will result in less than optimum results because of these modeling inaccuracies, cognitive limitations, and solution time constraints. Thus, the presence of the realities of a) through h) will, because of a combination of resource and intellectual constraints, lead to selection of an alternative that is best only within constraints posed by the model actually used. We may also observe that an

economically rational decision would only be appropriate when the decision situation structural model is such that an economically rational process is possible and desirable; and that the intellectual and resource conditions extant make substantive use of the rational actor model feasible.

Simon [336, 339, 340, 343] was perhaps the first to observe that unaided decisionmakers may not be able to make complete substantive, that is "as if", use of the model possible. The concepts of bounded rationality and satisficing represent much more realistic substantive models of actual decision rules and practices. We have described a variety of satisficing heuristic rules in Section 4. Unless very carefully developed and applied, these rules may result in very inferior decisions; decisions which are reinforced through feedback and repetition such as to result in experiences that are, by no means, the best teacher.

Of possibly even greater importance to information system design is the fact that completely economically rational processes may be neither desirable nor possible. Social, political, or legal rationality concerns may well prevail. And one of the other decision frameworks we describe here may well be more appropriate if these concerns are dominant over economic rationality concerns.

2. The Satisficing or Bounded Rationality Model. The decisionmaker looks for a course of action that is basically good enough to meet a minimum set of requirements. The goal is to "not shake the system" or "play it safe" by making decisions primarily on the basis of short term acceptability rather than seeking a long term optimum.

Simon introduced the concept of satisficing or bounded rationality as an effort to "... replace the global rationality of economic man with a kind of rational behavior that is compatible with the access to information and the computational capabilities that are actually possessed by organisms, including man, in the kinds of environments in which such organisms exist". He suggested that decisionmakers compensate for their limited abilities by constructing a simplified representation of the problem and then behaving rationally within the constraints imposed by this model. The need for this rests in the fact that many decisionmakers satisfice by finding either optimum solutions in a simplified world or satisfactory solutions in a more realistic world. As Simon says, "neither approach dominates the other " [341].

Satisficing is actually searching for a "good enough" choice. Simon suggested that the threshold for satisfaction, or aspiration level, may change according to the ease or difficulty of search. If many alternatives can be found, the conclusion is reached that the aspiration level is too low and needs to be increased. The converse is true if no satisfactory alternatives can be found. This may lead to a unique solution through iteration.

The principle of bounded rationality and the resulting satisficing model suggests that simple heuristics may well be adequate for complex problem solving situations. While satisficing strategies may well be excellent for repetitive problems

by encouraging one to "do what we did last time if it worked last time and the opposite if it didn't", they may also lead to premature choices that result in unforeseen disasterous consequences; consequences which could have been foreseen by more careful analysis. The heuristic decision rules described in Section 4 are all versions of satisficing strategies. A recent paper by Thorngate [372] provide useful descriptions of ways in which heuristic decision rules may be used and abused. Development of efficient and effective decision heuristics is a contemporary need for the analysis of decision behavior [56,59,60], the modeling of organizational and individual decisions [292,365] as well as for the design of normative systems to aid decisionmaking [316]. We believe that to be effective as well as efficient, heuristics will have to be developed in a very cautious way with due considerations for the many implications of the contingency task structure of a decision situation [326].

3. <u>The Bureaucratic Politics, Incrementalism, or "Muddling Through" Model</u>. After problems arise which require a change of policy, policy makers consider only a very narrow range of alternatives differing to a small degree from the existing policy. One alternative is selected and tried with unforseen consequences left to be discovered and treated by subsequent incremental policies. This is the incremental view.

In 1959, Lindblom postulated the approach called incrementalism, or muddling through [218-221], to cope with perceived limitations in the economically rational approach. Marginal values of change only are considered--and these for only a few dimensions of value, whereas the rational approach calls for exhaustive analy-

sis of each identified alternative along all identified dimensions of value. A number of authors have shown incrementalism to be the typical, common, and currently practiced process of groups in pluralistic societies. Coalitions of special interest groups make cumulative decisions and arrive at workable compromise through a give and take process that Lindblom calls "partisan mutual adjustment". He indicates that ideological and other value differences do not influence marginal decisions as much as major changes and that, in fact, considering marginal values subject to practical constraints will lead to agreement on marginal programs. Further, incrementalism can result in agreement on decisions and plans even by those who are in fundamental disagreement on values. However, incrementalism appears based on keeping the masses marginally content and thus may not be able to do much to help the greatly underprivileged and unrepresented. It is, of course, a combination of Diesing's social and political rationality. Boulding has compared incrementalism to "staggering through history like a drunk putting one disjointed incremented foot after another". Yet there have been a number of studies, such as Allison's study of the Cuban missile crisis [4], Steinbruner's case studies [359], and others [44, 108, 135, 400] which indicate this to be an often used approach in practice.

It is important to note [218] that Lindblom rejects (economic) comprehensive rationality even as a normative model and indicates that systems analysis will often lead to ill-considered, often accidental incompleteness. He indicates the following

inevitable limitations to analysis:

a) It is fallible, never rises to infallibility, and can be poorly informed, superficial, biased, or mendacious;

b) It cannot wholly resolve conflicts of value and interests;

c) Sustained analysis may be too slow and too costly compared with realistic needs; and

d) Issue formulation questions call for acts of choice or will, and suggests that analysis must allow room for politics.

A perceived more practical model process for decisionmaking than the rational actor model is, therefore, called for. The model is descriptive and is an extreme version of the bounded rationality model. Alternative models have been proposed [317].

The main features of the model proposed by Lindblom are:

(1) Ends and means are viewed as not distinct. Consequently means-ends analysis is viewed as often inappropriate.

(2) Identification of values and goals is not distinct from the analysis of alternative actions. Rather, the two processes are confounded.

(3) The test for a good policy is, typically, that various decisionmakers, or analysts, agree on a policy as appropriate without necessarily agreeing that it is the most appropriate means to an end.

(4) Analysis is drastically limited, important policy options are neglected, and important outcomes are not considered.

(5) By proceeding incrementally and comparing the results of each new policy with the old, decisionmakers reduce or eliminate reliance on theory.

(6) There is a greater preoccupation with ills to be remedied rather than positive goals to be sought.

In a very readable recent work concerning "muddling through" [221], Lindblom classified incremental analysis at three levels: simple, disjointed, and strategic. Incremental analysis is, as we have indicated, a good description of political decision making and is sometimes referred to as the political process model.

4. The Organizational Processes Model. Plans and decisions are the result of interpretation of standard operating procedures. Improvements are obtained by careful identification of existing standard operating procedures and associated organizational structures and determination of improvements in these.

The organizational process model, originally due to Cyert and March [68], functions by relying on standard operating procedures which constitute the memory or intelligence bank of the organization. Only if the standard operating procedures fail will the organization attempt to develop new standard procedures.

The organizational processes model may be viewed as an extention of the concept of bounded rationality to choice making in organizations. It is clearly an application of reasoning and rationality, as discovery and application of rules to cases. It may be viewed as a hybrid of economic and legal rationality.

It typically involves concrete operational thought, as we have indicated in Section 5. The main concepts of the behavioral theory of the firm, which is suggested as a descriptive model of actual choicemaking in organizations are:

A) Quasi-resolution of conflict: major problems are disaggregated and each subproblem is attacked locally by a department. An acceptable conflict resolution between the efforts of different departments is reached through sequential attention to departmental goals.

B) Uncertainty avoidance is achieved:

(a) by reacting to external feedback,

(b) by emphasizing short term choices, and

(c) by advocating negotiated futures.

C) Problem search:

(a) search is stimulated by encountering issues;

(b) a form of "satisficing" is used as a decision rule;

(c) search in the neighborhood of the status quo only is attempted and only incremental solutions are considered

D) Organization learning: organizations adapt on the basis of experience.

The organizational process model may be viewed as suggesting that decisions at time t may be forecasted, with almost complete certainty, from knoweldge of decisions at time t-T where T is the planning or forecasting period. Standard operating procedures or "programs", and education motivation and experience or "pro-

gramming" of management are the critical determinants of behavior for the organizational process model.

5. The Garbage Can Model - This relatively new model [63] views organizational decisionmaking as resulting from four variables: problems, solutions, choice opportunities, and people. Decisions result from the interaction of solutions looking for problems, problems looking for solutions, decision opportunities, and participants in the problem solving process. The model allows for these variables being selected more or less at random from a garbage can. Doubtlessly, this is a realistic descriptive model.

All five of the models, or frameworks, for decisionmaking have both desirable and undesirable characteristics. Conclusions may be drawn from these models and the fact that any of them may be relevant in specific circumstances. If we accept the facts that:

1. Decisionmakers use a variety of methods to select among alternatives for action implementation;
2. These methods are frequently suboptimal; and
3. Most decisionmakers desire to enhance their decisionmaking efficiency and effectiveness;

then we must conclude that there is much motivation and need for research and ultimate design and development of planning and decision support systems. But these five models make it very clear that improved planning and decisionmaking efficiency and effectiveness, and aids to this end, can only be accomplished if we understand human decisionmaking as it is as well as how it might

be, and allow for incorporation of this understanding in systemic process adjuvants. One of the requirements imposed on these adjuvants will be relevance to the individual and group decision-making structure [181,286,287,303,401]. Another requirement is relevance to the information requirements of the decisionmaker. We discuss both of these in this section of our survey and interpretation.

There have been many studies of group decisionmaking. These include the fundamental theoretical studies of Arrow [17] and others which show that, under a very mild set of realistic axioms, there is no assuredly successful and meaningful way in which ordinal preference functions of individuals may be combined into a preference function for society [17,196,279,302]. Conflicting values [378] are the major culprit preventing this combination. This has a number of implications which suggest much caution in using ordinal preference voting systems and any systemic approach based only on ordinal, possibly wholistic or heuristic, preferences among alternatives. Among other possible debilitating occurrences are agenda dependent results which can, of course, be due to other effects [280]. There have been a number of studies of group decisions and social and organizational interactions such as those by Bacharagh [19], Davis [69], Ebert and Mitchell [89], Einhorn, Hogarth and Klempner [92], Holloman and Hendrick [162], Janis and Mann [176, 177], Leavitt [211], Mintzberg [248], Penrod and Hastie [276], Schein [312], Shumway, et. al. [329], Simon [341], Vinokur and Burnstein [390,391] and in the edited work of Hooker, Leach, and McClennen [163].

Several systemic methods have been proposed for forming and aggregating group opinions as described in the works of Hogarth [155], Huber [169], Hylland and Zeckhauser [173], Rohrbaugh [295], Van de Ven and Delbecq [388]. An excellent survey of voting methods and associated paradoxes is presented by Fishburn [122] and by Plott [279].

Very definitive studies of the interpersonal comparison of utilities have been conducted by Harsanyi [145-147]. He argues convincingly that we make interpersonal utility comparisons all the time whenever we make any allocation of resources to those to whom we feel the allocation will do the most good. The prescription against such comparisons is one of two key restrictions which lead to the Arrow impossibility theorem. By using cardinal utilities, such that it becomes possible to determine preferences among utility differences (i.e. whether $u(a) - u(b) > u(b) - u(c)$), and interpersonal comparison of utilities, Harsanyi shows that Arrow's impossibility theorem becomes a possibility theorem. This is a major point in that it is generally not possible for a group to express meaningful transitive ordinal preferences for three or more alternatives even though all individuals in the group have individually meaningful transitive ordinal preferences.

Harsanyi is concerned primarily with organizational design [147]; how to design social decision making units so as to maximize attainment of social objectives or value criteria. He shows that rational morality is based on maximization of the average (cardinal) utility level for all individuals in

society. The utilitarian criterion is applied first to moral rules and then these moral rules used to direct individual choices. Thus, each utilitarian agent chooses a strategy to maximize social utility under the assumption that all other agents will follow the same strategy. Harsanyi recognizes a potential difficulty [147] with this particular utilitarian theory of morality in that it is open to dangerous political abuses as well as the numerous problems associated with information acquisition and analysis in a large centralized system. He posits a difference between moral rationality and game-theoretic rationality. He argues the unavoidable use of interpersonal cardinal utility comparisons in moral rationality and the inadmissibility of such comparisons in game theory. Much of Harsanyi's efforts concern game situations [146] in which outcomes depend on mutual interactions between morally rational individuals, each attempting to better their own interests. We will not attempt to explore here the very interesting subjects of bargaining, conflict, resolution, and negotiation; and the use of systems for planning and decision support to these ends. [21, 45, 269].

Harsanyi's concept of utilitarianism has occasionally been criticized for making inadequate provision for equity, or equivalently for social group equality. John Rawls, a philosopher, has presented a theory of justice [291] which involves a difference principle in which decisions are made under uncertainty rather than under risk. This difference principle advocates selection of the alternative

choice which is the best for the worst off member of society and is, therefore, the direct social analog of the maximin principle for the problem of individual decisions under certainty. Rawls uses a "veil of ignorance" concept in which individuals must determine equitable distribution of societies resources before they know their position in society. His argument is essentially that people will select a resource allocation rule that maximizes the utility of the worst off member of society. Discussions of some of the potential difficulties associated with Rawls' "social contract" justice theory are presented by Ellsworth and Gauthier in chapters of [163].

Other useful interpretations of cardinal utility and interpersonal utility comparisons have been made by Keeney and Kirkwood [194] and Keeney [195]. Their axioms allow development of a multiplicative group utility function in contrast to the additive utility function of Harsanyi. It is possible to more directly deal with equity considerations in a multiplicative group utility model than in an additive model. Papers by Bodily, Brock, and Keeney in [201] contain insightful discussions concerning group and individual utilities of a multiattribute nature. Ulvila and Snider, in [201], illustrate use of multiattribute utility models in negotiations.

We are particularly interested, here, in describing decisionmaking efforts in hierarchical organizations [241]. This leads naturally to a study of information processing in organizations and a description of how decisionmakers may determine information needs. While there have been a number of studies of group decisionmaking roles, and organizational behavior [357, 370], our efforts will be based primarily on those of Vroom and Yetton [394] and Huber [169].

Huber and Vroom and Yetton have indicated a number of potential advantages and disadvantages to group participation in decisionmaking. Since a group has more information and knowledge potentially available to it than any individual in the group, it <u>should</u> be capable of making a better decision than an individual. Group decisions are often more easily implemented than individual decisions since participation will generally increase decision acceptance as well as understanding of the decision. Also group participation increased the skills and information that members may need in making future organizational decisions. On the other hand, there are disadvantages to groups. They consume more time in decision making than individuals. The decisions may not fully support higher organizational goals. Group participation may lead to unrealistic anticipations of involvement in future decisions and resentment towards subsequent individual decisions in which they have not participated. Finally, there is no guarantee that the group will converge on a decision alternative.

Huber askes four primary questions, the answers to which determine guidelines for selection of a particular form of group decisionmaking. The Delta chart of Figure 6.1 indicates how the responses to these questions determines an appropriate form of group decisionmaking. There are a number of subsidiary questions concerned with each of the primary questions. For example, we may determine whether or not to involve others by posing questions involving: decision quality, understanding and acceptance, personnel development and relationships, and time required.

Vroom and Yetton have been much concerned with leadership and decisionmaking [394]. Their primary concern is with effective decision behaviors. They develop a number of clearly articulated normative models of leadership style for individual and group decisions. These should be of use to those attempting to structure normative or prescriptive models of the leadership style portion of decision situations which are capable of operational implementation. We will not illustrate these here since they essentially involve generalizations of Figure 6.1. It is the apparent goal of Vroom and Yetton to move beyond generalities such as the leadership style theory X-theory Y [211, 394]. They desire to come to grips with, and use explicitly, leadership behavior and situational variables to enhance organizational effectiveness.

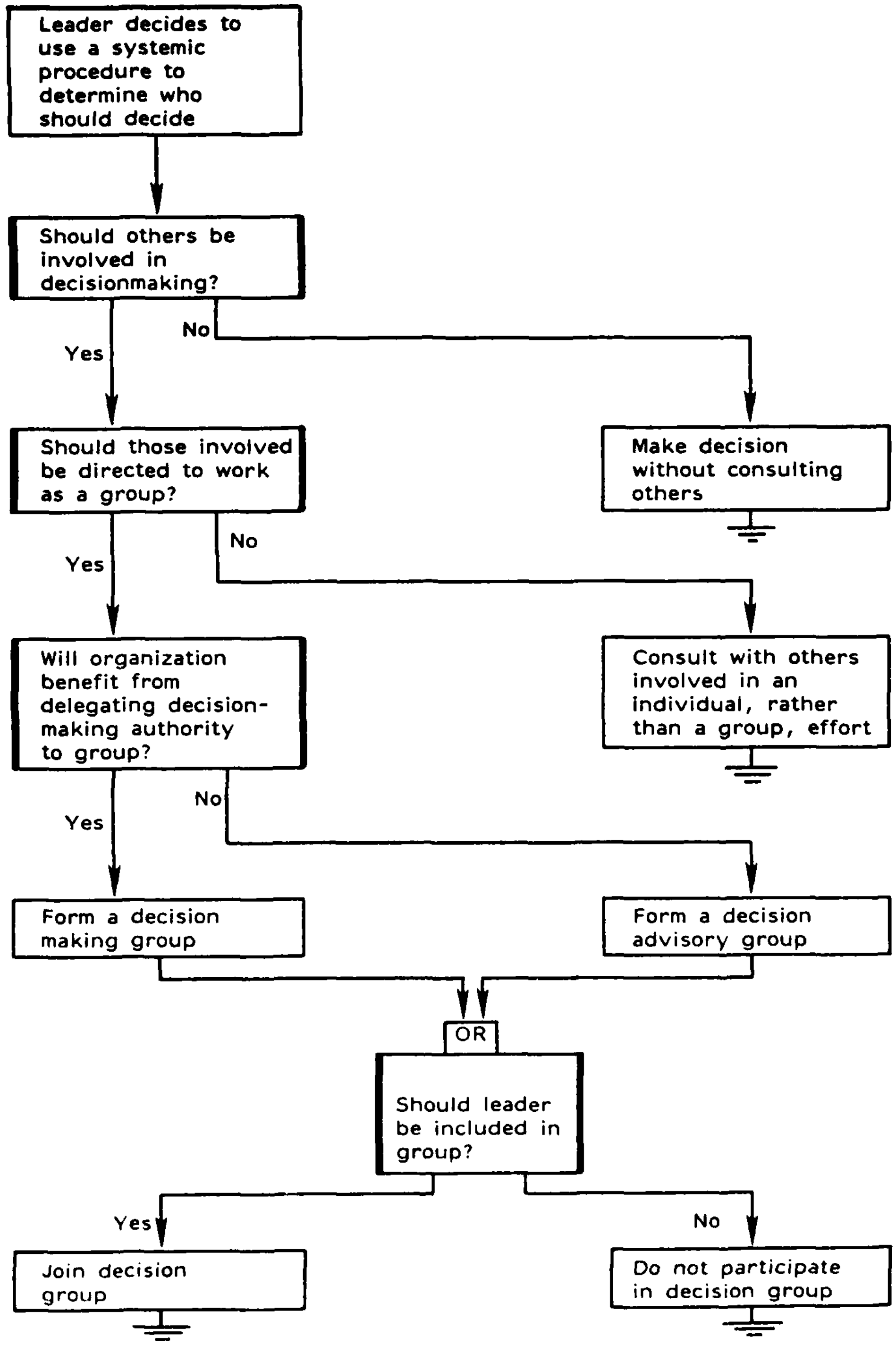

FIGURE 6.1 DELTA Chart on How to Decide Who Should Decide (After [169])

Much of our discussions in this section have concerned the evaluation component of various decisionmaking frameworks and organizational settings. Effective planning and decision support is based not only upon evaluation, but upon information acquisition and processing as well. We have emphasized this in our discussions thus far in terms of individual information processing behavior; but have not yet given explicit consideration to information processing behavior in organizations.

Keen [193] acknowledges four causes of inertia relative to organizational information systems. He indicates that: information is only a small component; human information processing is experiential and relies on simplification; organizational change is incremental and evolutionary with large changes being avoided; and that data is a political resource affecting particular groups as well as an intellectual commodity. Each of these suggests the importance of a knowledge of the way in which information is processed by organizations.

Of particular interest among studies concerning information processing in organizations are the works of Baron [28], Ebert and Mitchell [89], Fick and Sprague [110], Gerwin and Tuggle [129], Howell and Fleishman [165], Huber [169-171], Keen [193], Libby and Lewis [215], Lucas [225-228], O'Reilly [268], Shumway, et. al. [329], Simon [342], Starbuck and Nystrom [357], Taggart and Tharp [367], Tushman and Nadler [379], Tuggle and Gerwin [380], Wright [406], and Zedeck [409].

The purpose of systems for planning and decision support is to provide timely, relevant, and accurate information to system users such as to enhance human judgment, and decision-making efficiency and effectiveness, concerning resource allocations that affect issues under consideration. To enhance efficiency and effectiveness, available resources must be allocated and coordinated both in space, a hierarchy of decision-makers; and in time, as new information arrives and the environmental situation extant changes. Associated information acquisition, analysis, and evaluation and interpretation must, as a consequence, often be distributed both in space and in time. This must be accomplished selectively in space and time since different decisionmakers have different information needs. In addition, it will be physically impossible and often behaviorally undesirable to supply all relevant information to each decisionmaker in the hope that it will be effectively cognized and utilized. Further, differences in education, motivation, experiences with the environmental situation extant, and stress will influence cognitive information processing style. Consequently, a central task in the design of effective information systems is that of selection and choice of appropriate information system architecture to enhance selective information processing in order to provide each user of the system with the most appropriate information at the most appropriate time. Thus questions of information selection, information aggregation in space and in time, and the contingency task structure which is a

a function of the environment and the decisionmakers, become of major importance.

It is desirable that an appropriately designed system and the associated process, be capable of:

1) assisting in the evaluation of alternative plans and courses of action that involve formal operational thought processes;
2) assisting in the transfer of formal operational situations to concrete operational situations;
3) assisting in evaluation of alternative plans and courses of action that involve concrete operational thought processes;
4) assisting in the avoidance of information processing biases and poor judgmental heuristics;
5) assisting in the proper aggregation of information cues from multiple distributed sources;
6) assisting in the use of a variety of judgmental heuristics appropriate for given operational environments as natural extensions of a decisionmaker's normal cognitive style;
7) assisting, to the extent possible, in the determination of whether a formal or concrete style of cognition is most appropriate in a given situation;
8) assisting decisionmakers who need to use formal operational thought, and those whose expertise allows appropriate and effective use of concrete operational thought, to function together in a symbiotic and mutually supportive way.

Clearly there is a space-time and an organizational dependence

associated with these desired capabilities. Among the many concerns that dictate needs and requirements for automated support systems is the fact that decisionmakers must typically make more judgments and associated decisions in a given period of time than they can comfortably make. This creates a stressful situation which can lead, as has been noted, to the use of poor information processing and judgmental heuristics, especially since judgments and decisions are typically based on forecasts of the future.

There are formidable needs and issues to be resolved that are associated with the design of information processing and judgment aiding support systems. These relate to questions concerning appropriate functions for the decisionmaker and staff to perform. They concern the type of information which should be available and how this information should be acquired, analyzed, stored, aggregated and presented such that it can be used most effectively in a variety of potential operational environments. They concern design of information systems with strong space-time-environmental dependencies. They concern design of information systems that can effectively "train" people to adapt and use appropriate concrete operational heuristics in those environments in which inexperience dictates initial use of formal operational thought. They concern design and use of information systems that support environmentally experienced decisionmakers in the use of a variety of effective concrete

operational heuristics. And because of their use by multiple decision makers, these tasks must be accomplished in a parallel architectural fashion.

Huber [170-171] and Tushman and Nadler [379] have developed a number of propositions, based on their own research and upon the research of others, reflecting various aspects of information processing in organizations. There are a number of fundamental propositions developed by Tushman and Nadler which relate to the development of a model of an organization as an information processing system. These fundamental propositions include [379]:

FP1: Tasks of organizations and their subunits vary in uncertainty and risk variables.

FP2: As uncertainty and risk increase, so also does the need for information and increased information processing capability.

FP3: Capacities and capabilities in information processing will vary as a function of organization structure.

FP4: Organizational effectiveness increases as the match between information processing requirements and information processing capacity and capacity increases.

FP5: Effectiveness of organizational units will depend upon their ability to adapt their internal structures overtime to meet the changed information processing requirements that will be associated with environmental changes.

In an effort to enhance efficiency, organizational information processing typically requires selective routing of messages and summarization of messages. Huber [171] identifies six variables associated with the routing of messages. Six propositions relative to message routing are identified and associated with these variables. Three propositions are associated with delay in messages, eight with organizational message modification, and four with message summarization. Table 6.1 presents an interpretation of the impacts of the variables associated with organizational information processing and the probabilities of routing, delay, modification and summarization of messages. It is possible to infer a few impacts not discussed in this noteworthy work of Huber. Most of these simply relate to the observation that if something happens to decrease the probability of sending a message unmodified then the probability of the message being delayed and/or modified is increased.

Identification of other variables which influence information processing by organizations would represent a desirable activity. To determine how these information processing variables are influenced by the information processing biases of individuals discussed in Section 3 would seem especially desirable in terms of the likely usefulness of the results and the need for an expanded theory of group information processing biases. There appears to have been only limited results obtained in the area of cognitive information processing biases

TABLE 6.1 Cross Impact Matrix Between Variables Affecting Organizational Information and Associated Activities

	A) PROBABILITY OF MESSAGE ROUTING (IN UNDISTORTED, UNSUMMARIZED FORM)	B) PROBABILITY OF MESSAGE DELAY	C) PROBABILITY OR EXTENT OF MESSAGE MODIFICATION	D) PROBABILITY OR EXTENT OF MESSAGE SUMMARIZATION
1. INCREASES IN ECONOMIC AND OTHER COSTS OF A TRANSMISSION SENDING	−	⊖	−	−
2. INCREASES IN WORKLOAD OF SENDING UNIT	−	+	+	−
3. PERCEIVED RELEVANCE OF MESSAGE TO SENDING UNIT	+	⊖	⊖	+
4. DECREASES IN PERCEIVED GOAL ATTAINMENT, STATUS OR POWER OF THE SENDING UNIT RESULTING FROM ROUTING	−	⊕	⊕	
5. INCREASES IN PERCEIVED GOAL ATTAINMENT, STATUS OR POWER RESULTING FROM MODIFICATION	⊖		+	
6. PERCEIVED GOAL ATTAINMENT, STATUS, OR POWER OF THE SENDING UNIT	+	⊖	⊖	
7. FREQUENCY OF PAST COMMUNICATION OF SIMILAR MESSAGES	+	⊖	⊖	
8. PERCEIVED TIMELESS OF MESSAGE FOR THE RECEIVING UNIT		−		
9. NUMBER OF ACTIVE COMMUNICATION LINKS IN THE CHAIN BETWEEN RECEIVER AND SENDER	⊖	+	+	+
10. DECREASE IN STRESS OF THE RECEIVER PERCEIVED BY THE SENDER TO RESULT FROM MODIFICATION	⊖		+	
11. AMOUNT OF DISCRETION ALLOWED ALTERING OR CHOOSING THE MESSAGE FORMAT	⊖		+	
12. INCREASED INDIFFERENCE BETWEEN ACTUAL MESSAGE CONTENT AND TRANSMITTER'S DESIRED CONTENT	⊖	⊕	+	
13. INCREASED IN PERCEIVED AMBIGUITY OF DATA ON WHICH MESSAGE IS BASED	⊖	⊕	+	
14 INCREASES IN SAVINGS DUE TO SUMMARIZATION				+

+ = ENHANCING IMPACT SEEN BY [illegible]

− = INHIBITING IMPACT SEEN BY [illegible]

⊕ = INFERRED ENHANCING IMPACT

⊖ = INFERRED INHIBITING IMPACT

and use of inferior heuristics on the part of groups. Thus many of the areas discussed in Section 3 and 4 could be extended to groups.

Especially noteworthy concerning results that have been obtained in this area are the groupthink studies of Janis and Mann reported in [177]. Groupthink is a collective pattern of defensive avoidance, a concurrence seeking tendency of highly cohesive groups. When groupthink occurs, people develop rationalizations to support selectively perceived illusions or wishful thinking about issues at hand and collectively participate typically, in development of a defensive avoidance pattern. In groupthink, a group collectively falls victim to one or more of the cognitive biases described in Section 3.

Among the conditions which lead to groupthink are: high cohesiveness, insulation, lack of use of systemic procedures for search and appraisal, highly directive leadership, and a contingency task situation which leads to high stress. Among the symptoms of groupthink cited by Janis and Mann are [177]: an illusion of invulnerability, collective rationalization, belief in inherent group morality, excessive pressure against dissenting views, self censorship, illusions of unanimity, and members who shield the group from disconfirming information. They cite a large number of case studies involving groupthink; cases where incrementalism and bureaucratic politics were the dominant decisionmaking framework. Nine prescriptions are offered to avoid groupthink:

1. The group leadership should be noncommitted to particular alternative courses of action;
2. The group leader should encourage critical evaluation;
3. "Devil's advocates" should be included in the group;
4. ubgroups should be formed, allowed to function independently, and then meet with other subgroups to express generated ideas and resolve differences;
5. A variety of alternative scenarios of potential opponents intensions should be developed;
6. Second opinion meetings should be held to allow full expression of doubts and rethinking of the issue;
7. Experts with opposite viewpoints to the majority view should be encouraged to present challenging views;
8. A small "policy" subgroup should always discuss subgroup deliberation with the larger group to attempt to obtain discomfirming feedback; and
9. Independent policy planning and evaluation groups should be formed.

The suggestions offered in Section 3 to avoid cognitive bias and to ameliorate the effects of those that do occur appear capable of application to groups as well as to individuals. Explicit study of group and organizational bias that would compliment and extend existing studies [16, 19, 129, 155, 173, 257, 276, 279, 280, 388, 390, 391, 394] of group and organizational decision making should yield results that are valuable for the design of planning and decision support systems.

A major difficulty in cognitive information processing seems to be failure to identify and use an appropriate structure that allows appropriate weighting of observed data. Investigation of

the effects of various structured information processing/ decision aiding protocols upon the acquisition, analysis, and interpretation of information and its integration with judgment and decision making activities would appear to be a contemporary need in information system design. There are six elements found in explicit argument [376]:

1. claims or hypotheses
2. grounds or foundations to support the claims
3. warrants or justification for the grounds or foundations
4. backing or the general body of information that is presupposed by the warrant
5. modal qualifiers or circumstances contingencies or restrictions which will have to exist in order that the warrant truly supports the grounds
6. possible rebuttals or circumstances, contingencies, or restrictions which, if they exist,will refute or diminish the force of the warrant would appear to be the elements of interest for development of structured protocols.

A simplified block diagram of the interaction among these elements is given in Figure 6.2. The information processing "structure", consisting in part of the decisionmakers view of possible and probable action courses and the "decision situation model," is specified by elements 3-6. Element 2, the "grounds", comprises the situational data pertaining to the operational conditions extant. The claim, element 1, is the empirical statement which is supported by other elements in this information processing structure.

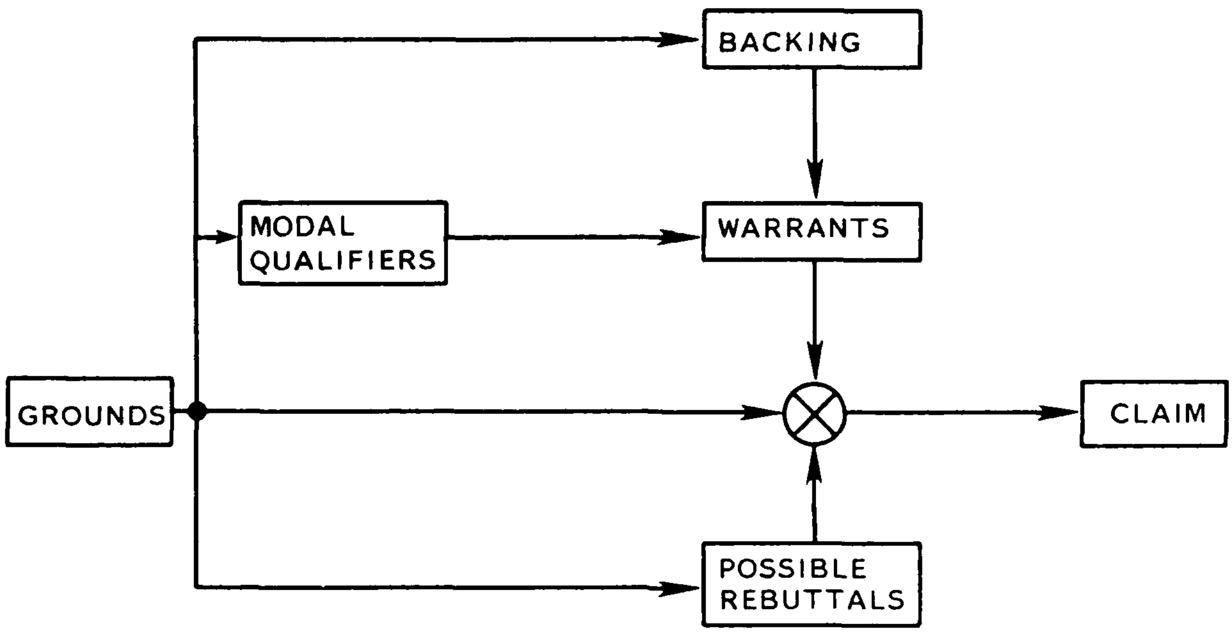

Figure 6.2 A possible Structure for Information Processing Based Upon the Six Elements of Logical Reasoning

Toulmin shows, through examples, that the six elements for logical argument and reasoning can be used as a model for rational reasoning in a number of areas including: law, science, the arts, management, and ethics. This structured information processing model is also sufficiently general to accommodate analytical hierarchical inference [165,306]. Thus it may well provide a structured framework for information processing that can accommodate a variety of information processing styles and approaches ranging from the purely qualitative and affective, to reasoning by analogy which may be a blend of qualitative and quantitative, to quantitatively based filtering and detection algorithms.

Use of a structured information processing format may reduce the tendency for message distortion due to the exacerbating variables presented in Table 5.1, perhaps to a considerable extent. Mitroff and Mason [255] have presented some suggestions concerning use of structured logical reasoning to cope with ill structured policy problems and the often occuring divergence between opposing formulations and perceptions of large scale issues.

Information summarization is needed in information systems for a variety of reasons. Procedures to condense and organize information into a form that can be managed and used in an efficient manner are, therefore, important. The structured information processing model suggested here may well provide organizational support for message aggregation and integration that will accommodate and encourage effective information summarization. We can only postulate that this framework may accommodate both recep-

tive and preceptive styles of processing and summarization of information, that it will also accommodate non numerical and numerical information; and thus hopefully enable rapid conversion from one to the other as needed or desired for different situations.

In this section we have examined a number of frameworks for decision making. Our particular interest is in the description of these frameworks in a way compatible with and supportive of the effective design of systems and processes to aid groups in planning and decision making. We describe a number of "rational" ways in which groups make decisions and pay particular attention to information processing needs in group decision making. Use of a structured protocol for information processing in systems for planning and decision support is suggested as a generic suggestion of potential ways to detect and correct possible cognitive biases that affect many judgment tasks.

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